Physiology Class-Book.

Name

Physiology Class-Book.

—BY—

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INDEX.

PAGE

Absorption.....52—54
Accommodation.....120
Adductors.....76
Air passages.....30
Air vesicles.....32
Alimentary canal.....42
Alcohol.....126
Anatomy defined.....1
Aqueous humor.....118
Arteries.....18
Articulations.....70–72
Astigmatism.....120
Atmosphere.....36—38
Auditory cells.....112
Auditory canal.....110
Automatic action.....98
Axis cylinder.....84
Bathing.....82
Bile.....50
Blind spot.....118
Blood.....10—14
Bone cells.....66
Bowels, care of.....52
Brain.....90
Caffeine.....128
Canaliculi.....66
Capillaries.....20
Carbon dioxid.....38
Cells.....2—4
Cerebellum.....92
Cerebro-spinal system.....90
Cerebrum.....90
Choroid coat.....116
Ciliary muscle.....118
Circulation of blood.....16—20
Circulatory organs.....16—18
Coagulation of blood.....10
Cochlea.....112
Coffee.....128
Conjunctiva.....122
Cornea.....116
Cranial nerves.....92–94
Crystalline lens.....118
Cuticle.....80
Deglutition.....50
Dermis.....80
Dialysis.....26
Diaphragm.....32
Digestion.....40—52
Digestive glands.....44
Digestive organs.....40
Digestive processes.....44
Dissection of
Cat.....64
Heart.....16
Lungs.....30
Dissectional review.....64
Ear.....110—114
Effects of alcohol.....126
Endosteum.....66
Epidermis.....80
Epithelial cells.....32—60
Epithelial tissue.....2
Eustachian tube.....110
Excitant fibres.....86
Excretion.....58—60
Excretory organs.....58
Exercise.....78, 124
Experiments to illustrate
Accommodation.....120
Blind spot.....118
Breathing.....34
Composition of bones.....66
Digestion.....40
Digestion of fats.....50
Effects of alcohol.....126
Function of skin.....82
Heart's action.....18
Insensible perspiration.....60
Light.....114—116
Osmosis.....26
Properties of blood.....10
Properties of carbon dioxid.....88
Properties of oxygen.....36—38
Purpose of mastication.....48
Reflex action.....96
Separation of haemoglobin.....12
Sound.....118
Stomach digestion.....50
Structure of eye.....118
Structure of ear.....112
External ear.....110
Extensors.....76
Eyeball.....116
Fatigue.....76
Flexors.....76
Focusing power of the eye.....118
Foods.....56—58
Gastric glands.....48
General sensations.....104
Glands.....46
Glycogen.....48
Gray matter.....84
Haemoglobin.....12
Hair.....80
Haversian canals.....56
Hearing.....108—114
Heart.....18
Histology defined.....1
Hygiene defined.....1
Hygiene of
Bones.....72
Circulation.....20
Digestive organs.....50—52
Ear.....112
Eye.....122
Muscular system.....78
Nervous system.....124—128
Respiratory organs.....34—36
Skin.....82
Inhibitory fibres.....84
Insalivation.....48
Internal ear.....112
Intercostal muscles.....34
Intestinal digestion.....50
Intestinal glands.....46
Involuntary action.....96
Involuntary muscles.....74
Iris.....116
Joints.....70—72
Kidneys.....58
Labyrinth.....112
Lacteals.....54
Large intestine.....44
Larynx.....30, 110
Levers.....70
Light.....114
Liver.....46
Longsightedness.....120
Lungs.....30, 60
Lymph and lymphatics.....22–24
Lymphatic glands.....24
Lymph movements.....24
Marrow.....66

292690

PAGE

Mastication 48
Matrix 80
Medulla oblongata 92
Medullary sheath 84
Membrana tympani 110
Mental action 98
Middle ear 110
Morphea 128
Mouth 44
Mucous membrane 42
Muscular stimuli 76
Muscular system .... 74—78
Muscle cells 74
Muscles of alimentary canal 42
Nails 80
Narcotics .... 126—128
Nerves 84
Nerve cell 84
Nerve center 84
Nerve fibre 84
Nervous action .... 96—98
Nervous control of
    Blood supply 100
    Respiration 100
    Digestion 102
Nervous ganglia 84
Nervous impulse 76, 84, 86
Nervous system 84, 128
Nervous tissue 84
Nicotine 128
Nitrogenous foods 56
Observation of
    Blood 10
    Bone 66
    Circulatory organs 16
    Muscles 74
    Nails 80
    Skin 80
    Tissues 1
Oesophagus 44
Organs defined 6
Osmosis 26
Osseous system .... 66—72
Oxygen 36
Pancreas 46
Pancreatic juice 50
Pepsin 50
Perimysium 74
Periosteum 66
Perspiration 60
Pharynx 44
Physiology defined 1
Plan of maintaining life 6
Plan of placing muscles 76
Plan of skeleton 68
Plasma 14
Pleura 32
Primitive sheath 84
Problem in
    Absorption 54
    Excretion 60
    Hearing 112
    Osmosis 26
    Reflex action 98
    Ventilation 34
Protoplasm 4
Pupil of eye 116
Red corpuscles 12
Red marrow 68
Reflex action 96
Respiration .... 30—36
Respiratory organs 30
Retina 116
Rods and cones 116
Rotators 76
Salivary glands 46
Salts 58
Sclerotic coat 116
Semi-circular canals 112
Sensations .... 104—122
Serum 14
Shortsightedness 120
Sight .... 114—122
Skeleton 68
Skin .... 80—82, 60
Sleep 124
Small intestine 44
Smell 106
Sound 108
Spinal cord 92
Spinal nerves 94
Sphincters 78
Stimulants .... 126—128
Stomach 44
Stomach digestion 50
Sympathetic system 88
System defined 6
Taste 106
Tea 128
Teeth 44
Temperature sense 106
Theine 128
Thoracic duct 24
Thorax .... 32—34
Tissues .... 1—2
Tobacco 128
Tongue 44
Touch 104
Tympanum 110
Urea 60
Urine 60
Uriniferous tubes 60
Veins 18
Vestibule 112
Villi 54
Vitreous humor 118
Vocal cords 110
Voice 110
Voluntary action 96
Voluntary muscles 74
Water 56
White corpuscles 12
White matter 84
Yellow spot 118

PREFACE.

THE PHYSIOLOGY CLASS-BOOK is the outgrowth of an attempt to combine the "text-book" and "lecture" methods of teaching Physiology, and has been prepared for the use of students in the Warrensburg State Normal School. Recognizing the pedagogical principal that to tell a pupil what he can easily find out for himself deprives him of an opportunity to think, while withholding from him what he cannot find out, wastes his time in useless endeavor, the aim has been to state in clear, concise English what the pupil *must be told* about the subject. This information is intended to serve as a basis for the *recitation*, and is to be supplemented by text-book references, lectures, experiments, observations, and illustrative drawings. The blank pages are for the recording of experiments, observations, etc., by the pupil, so that the completed book may contain his own work as well as the subject matter furnished him.

Throughout, the subject has been treated from the standpoint of a natural science. Enough has been said and written of late upon this view of Physiology to make a restatement of argument unnecessary here. Such a treatment, however, necessitates a clear statement of the principles underlying the science, and a logical arrangement of the parts, based, if possible, upon some central underlying truth. The central idea in the science Physiology is Nature's plan of *maintaining life*. For this one purpose all the different parts of the human organism are made, directly or indirectly, to serve. The aim has been to arrange the parts of the subject in such an order that each successive step in the study will reveal more and more of this plan to the pupil.

Further, in teaching a subject as a science, the appeal must be made to the pupil's reasoning powers rather than his memory, and sufficient experimental and observational work must be done to furnish clear conceptions—the necessary basis for correct thinking. Physiology work should be supplemented by laboratory practice. Where this cannot be arranged for, class experiments and observations should be furnished by the teacher. The experiments and observations given in this book are intended for class purposes. The list is suggestive, rather than exhaustive, and contains such as require little or no apparatus.

Next to observations and experiments, in forming clear conceptions, are properly made diagrams and drawings. Of the different kinds, those which show fundamental relations and the connection of different organs are of most value. They may be drawn upon the blackboard or executed on heavy manilla paper with colored pencils. A set of the drawings, to be used in connection with this book, is in course of preparation, and will be furnished by the publishers.

The reference blanks are to be filled at the teacher's suggestion, with the page numbers of available books upon the given subjects. For reference work by the pupil, the following books are recommended: Martin's Human Body, Intermediate Course; Jenkin's Advanced Lessons in Physiology; and Blaisdell's Our Bodies. For extended study, the advanced works of Foster, Martin, Flint, and Kirke, are recommended.

The necessity of keeping such a book small enough for class purposes accounts for the crowded condition of many of the pages and the omission of considerable material found in books of similar nature. Still, it is believed that the principles underlying the science of Physiology have been stated and the method suggested for mastering them.

WARRENSBURG, Mo., Aug. 30, 1895.

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Directions for Work.

(For the Pupil.)

1. The following printed notes are not intended to take the place of a text-book, but are to be used in connection with books. The student is recommended to consult as many books as he has at his disposal on the various subjects, in addition to looking up the references.

2. Copy on the blank pages the different drawings used in illustrating the subject. The drawing in each case should be placed directly opposite that portion of the printed notes which it is intended to illustrate.

3. When experiments are performed, specimens shown, or dissections made in class, the important things done and seen should be noted and written in ink on the blank pages.

4. Notes dictated in class and important facts obtained from books or other sources may also be inserted.

5. In the preparation of lessons, commit nothing to memory, but *think about and try to understand* what you see, hear and read.

6. Keep a neat and orderly book and do not allow the written work to lag.

7. Never attempt to copy a drawing until you thoroughly understand it. Then be sure that it is sufficiently accurate in detail to show what it is intended to illustrate.

8. Where questions are asked in the printed notes it is expected that the pupil shall think out the answers. If this is carefully done in each case, the work which follows will be made easier.

9. The pupil is his own teacher. Books, specimens, drawings, and the instructor, can only serve him as aids in teaching himself. He will therefore be careful that he does not pass over any portion of the subject without understanding it.

General Structure and Function of the Body.

Methods of Study. The different ways of studying the human body are designated by the terms, Anatomy, Physiology, and Hygiene.

1. A study of the structure of the different parts is called Anatomy. Anatomy is of two kinds, known as Gross Anatomy and Histology. Gross Anatomy is a study of the rough, coarse structure—those parts which can be readily seen with the naked eye. Histology is a study of the minute structure—those parts which are too small to be seen with the naked eye and whose study requires the use of a miscroscope.

2. The study of the function or use of the different parts of the body and their relation to each other is termed Physiology.

3. A study of the ways of taking care of the body and keeping its parts in good working order is called Hygiene. The conditions which must be observed in doing this are termed the "laws of health."

Sources of Information. Information concerning the body may be obtained from many sources. The body itself, books which have been written about the body, the bodies of other animals, experiments, models, and charts will each contribute something to the subject. The true student will not confine his investigations to the printed page, but will seek information from all sources.

The Tissues. The different kinds of material which compose the body are called tissues. These are to the body what the wood, stone, plaster, and other building materials are to a house. In fact, the tissues have been called *the building materials of the body*. The most important tissues are as follows:

1. Osseous or bony. 2. Muscular, of two varieties, the voluntary and involuntary. 3. Two varieties of nervous tissue. 4. Elastic and inelastic connective tissue. 5. Cartilagenous. 6. Adipose or fatty. 7. Epithelial. 8. Epidermal.

OBSERVATION.—Select the leg of some small animal as a cat, rabbit, frog, or chicken. On the outside observe the EPIDERMAL tissue in the form of cuticle and hair, claws, or feathers, according to the specimen. With a sharp knife lay open the skin and observe that it is attached to the parts underneath by CONNECTIVE tissue. Next observe the amount and ar-

rangement of the MUSCULAR tissue. With a blunt instrument separate the muscles, by tearing apart the connective tissue sheaths, and find the rough strips of connective tissue (the tendons) which attach them to the bones. Find near the central part of the leg some white glistening cords (nerves) which form one variety of NERVOUS tissue. At the end of the bones (OSSEOUS TISSUE) find a layer of CARTILAGE. The ADIPOSE or fatty tissue is found immediately beneath the skin and in between the other tissues. Describe the appearance of the muscular, nervous, adipose, and cartilagenous tissues. What purposes are osseous, connective and epidermal tissue, made to serve?

Properties and Uses of Tissues. Each tissue is made to serve some definite purpose in the body. It is able to serve this purpose because of certain important properties which it possesses. Osseous tissue, for example, is hard, tough, elastic, stiff, and compact. On account of these properties it is used to form the framework of the body, to protect delicate organs, and to form levers. Muscular tissue, likewise, has the remarkable property of contractility, on account of which it is used in the body to produce motion. If the entire list of tissues were examined it would be found that each is peculiarly fitted for the purpose it is made to serve. Show how connective tissue is adapted to its purpose in the body.

Classes of Tissues. According to their purpose in the body, tissues are classed as *supporting*, *active*, *storage* and *protective*. The *supporting* tissues are those which hold the body together and form supports for the more delicate parts. Bone, cartilage, and connective tissues belong to this class. The *active* tissues are those through which the body expends its energy or does work. Muscular and nervous tissues are the most important members of this class. *Storage* tissues are those which contain nourishment that the body may use at some future time. Of this class, fatty or adipose tissue is the best example. The best example of *protective* tissues are the epidermal and epithelial. The former covers and protects the outside of the body and the latter the internal cavities to which the air penetrates.

Composition of Tissues. The tissues are made up of minute particles, called cells. These are, for the most part, too small to be seen with the naked eye. In the body they vary in size from 1-4000 to 1-500 of an inch in diameter. They also vary in shape and general properties to suit their place in the body. A tissue is simply a collection of similar cells cemented together. There are therefore as many kinds of cells in the body, as there are tissues. They are named according to the tisues which they help to form, muscular cells being found in muscular tissue, osseous cells in osseous tissue and so on for the others.

Structure of a Typical Cell. The outside part of the cell is usually hardened forming the *cell wall*. This wall surrounds a transparent, jelly-like, substance called the *protoplasm*. Within the protoplasm is a denser part known as the *nucleus*. In some cells there is yet a denser part of the nucleus called the *nucleolus*. Copy drawings.

Properties and Uses of Parts. The *cell wall* is supposed to be formed by the hardening of the protoplasm on the outside. It protects the more delicate parts of the cell. The *protoplasm* resembles in appearance the white of a raw egg. When alive it is capable of a slight motion and is sensitive. It is able to absorb and appropriate liquid food and to grow. It is the living, active portion of the cell and is the one part which is absolutely essential. The other parts may be absent from the cell but never the protoplasm. The *nucleus* differs from the protoplasm in being denser. Its function is not fully understood, but it is supposed to give the cell the power of reproducing itself. Cells from which the nucleus is absent are unable to form new ones.

Growth of Cells. The cells of the body, to a great extent, prepare the material for their growth from substances absorbed from the blood. These consist of various substances dissolved in water, forming a *liquid food*, and an active element obtained from the atmosphere called *oxygen*. Within the cell, the oxygen and certain elements of the liquid food unite. As a result of this union, heat is liberated, waste matter is formed, and new material, resembling the protoplasm, is produced. The heat keeps up the requisite warmth of the cell; the waste matter flows out into the blood; the new material is added to the cell and increases its size.

Formation of New Cells. New cells are always formed from old ones. One process by which this is accomplished is called cell division. By this process a single cell will, after attaining its growth, separate into two or more new cells. (See drawing.) The new cells thus formed repeat the history of their parents, absorbing liquid food and oxygen, growing, and then dividing to form other new cells.

Special Work of Different Cells. There are certain kinds of work such as absorption, growth, and reproduction, which all the cells perform in common and by which they are individually benefited. In addition to this, each kind of cell has a *special* work to perform—a work which benefits, not only the cell itself, but the entire body as well. The special work of muscular cells is to cause motion; that of gland cells is to secrete liquids. Furnish other illustrations of the special work of cells. Like individuals working at different trades, the several classes of cells have specialized in some particular and have become able to do well one kind of work. Is this an advantage or disadvantage to the body? Compare "division of labor" as carried on by a community to that carried on by the cells in the body.

Importance of the Cells. A knowledge of the structure, growth, and work of cells is the first step toward a clear understanding of the body. For the body grows by the growth and reproduction of its cells. All of its work is done by them. It is nourished and life maintained by nourishing and keeping alive the cells which compose it. The cell is thus the unit of structure and function.

Organs. Tissues do not work singly but are grouped together forming organs. An organ is a part of the body which has some special work to perform. The eye is an organ of sight. The hand is an organ for grasping. Name other examples. What different tissues are represented in the hand?

Systems. Organs as a general thing, do not work singly, but are grouped into systems. A system may be said to be a collection of organs working together to accomplish some particular end or purpose. The heart, arteries, veins, and capillaries, for example, have for their common work the circulation of the blood and together they form the circulatory system. Supply other illustrations.

The most imporantant systems of the body are as follows: 1. Digestive. 2. Muscular. 3. Nervous. 4. Respiratory. 5. Excretory. 6. Circulatory. 7. Osseous.—State purpose of each of these systems.

The Maintenance of Life. This is the one purpose for which all the organs and systems of the body work. While the nature of life is, as yet, a great mystery, the plan of maintaining it in the bodies of animals is fairly well understood. Physiologically speaking, the life of the body may be regarded as the sum of the lives of the cells which compose it. Hence all effort at maintaining life must be directed toward the cells. By keeping them alive and active the body is kept alive.

For the purpose of ministering directly to the wants of the cells, a liquid (the blood) is prepared and circulated thoughout the body. What do the cells receive from the blood? What does the blood receive from the cells?

Certain of the systems do their part in maintaining life, by working for the blood. For, in order that it may discharge its functions toward the cells, it must be supplied with liquid food and oxygen, have its impurities removed, and be kept in constant circulation. What systems perform these services for the blood?

Other systems help maintain life by working for the general welfare of the body, supplying it with food, clothing, and shelter, and guarding it against external danger. Copy and study the drawing.

General Summary. The body is an aggregation of different kinds of cells. *Like* cells are grouped together forming tissues. The tissues are grouped into organs and the organs into systems. The systems are grouped to form the body, and all parts work together to maintain life.

General Plan of the Body. The body consists of a large central portion, the trunk, to which is attached the head, arms, and legs. The arms, together with the hands, are known as the upper extremities, while the legs and feet form the lower extremities.

Within the head and trunk are three important cavities; the cranial, thoracic, and abdominal. The *cranial* cavity, located in the head, holds the

brain while a downward extension through the spinal column contains the spinal cord. The *thoracic* or chest cavity, in the upper part of the trunk, supplies space for the heart and lungs. In that portion of the trunk below the chest is the *abdominal* cavity. It contains the liver, stomach, intestines, and other important organs and is separated from the cavity above by the diaphragm. Copy drawing.

The outside of the body is covered and protected by the skin. The different cavities are lined with membranes. The cavities which air can enter are lined with mucous membranes; those from which air is excluded are lined with serous membranes. The lining membrane of the chest is called the pleura and that of the abdomen is called the peritoneum.

A bony framework, the skeleton, gives form to the body and provides support for the different organs.

References:

Review Questions. 1. Define Anatomy Physiology, and Hygiene. 2. How does Gross Anatomy differ from Histology? 3. What are "laws of health"? How is disobedience to them punished? 4. From what different sources may information concerning the body be obtained? 5. State objections to confining the study of the body to books. 6. Why call a tissue a building material? 7. Show that the use made of a tissue depends upon its properties. 8. Name an example of each of the different classes of tissues. 9. Draw a typical cell and name its parts. 10. Why is the protoplasm considered the most important part of the cell? 11. How do cells increase in numbers? 12. How does the body grow? 13. In what sense do the cells of the body practice "division of labor"? 14. Define and give illustrations of organs and systems. 15. How does keeping the cells alive keep the body alive? 16. What is liquid food? Illustrate. 17. Name and locate the principal cavities of the body. 18. What cavities are lined with mucous membrane? What kind with serous?

The Blood.

Two Liquids of similar nature are found in the body, known as the blood, and the lymph. The former is kept moving rapidly through a system of tubes called the blood vessels, while the latter moves slowly through another system of tubes called the lymphatics. Both minister to the wants of the cells. Packed away in the different tissues of the body, the cells have no way of procuring the materials needed for their growth and repair or of getting rid of the impurities which result from their activities. These liquids perform the double function of bringing to them the different materials which they need and of removing their impurities. The study of the lymph and its special work will be deferred to a later period.

Physical Properties of the Blood.

EXPERIMENTS. Secure through the assistance of a butcher two specimens of blood. One should be collected, without stirring, in a large open-mouthed bottle with straight sides, and kept in a quiet place for one or two days. The other should be collected in a larger vessel, for convenience, an empty fruit can, and, while cooling, be stirred with a bunch of small switches. This process is called "whipping the blood" and its purpose is to prevent coagulation. Fibrin, the coagulating agent, is thus removed as fast as it is formed. A portion of this defibrinated blood should be kept until it loses its oxygen and becomes a dark red color.

a. Examine the first specimen to see the effect of coagulation. The central dark mass is called the CLOT and the liquid surrounding it is called the SERUM. The serum should appear nearly colorless. Sketch the vessel and its contents locating the two parts.

b. Pour some of the defibrinated blood upon the surface of water, in a glass vessel. Does it remain on the surface or sink to the bottom? What does this experiment prove with reference to the comparative weights of blood and water?

c. Place a small amount of the dark, defibrinated blood in a large test tube or bottle and thin it by adding an equal amount of water. Then place the hand over the mouth of the vessel and shake until the blood is thoroughly mixed with the oxygen of the contained air. Compare with a portion of the blood not mixed with oxygen and notice any difference in color. What effect has oxygen upon the color of the blood?

The above and other experiments show the blood to be heavier and denser than water; to have a faint odor and a slightly sweetish taste; to present a bright red appearance if it contains oxygen and a dark red if oxygen is absent; and to possess the power of coagulating.

Coagulation refers to that property of the blood which enables it to thicken or clot when exposed to some unnatural condition. The cause of coagulation is *fibrin*—a clear, stringy, solid substance which, by its contraction separates the corpuscles from the liquid portion of the blood and binds them into a mass, called the clot. Fibrin does not exist in normal blood; but is formed as coagulation takes place. It is formed from materials which are always present in the blood known as the *fibrin factors.* The conditions which induce coagulation must be such as will cause the fibrin factors to change into fibrin. Name some of these conditions. What important purpose is served by the coagulation of the blood?

Composition of the Blood. To the naked eye the blood has the appearance of a simple liquid. When examined with a powerful microscope, however, it is seen to be made up of a clear, transparent liquid in which float great numbers of small, round bodies. The liquid portion is known as the *plasma*; the small bodies are called *corpuscles.* The corpuscles are of two kinds; the *red* and the *white.*

OBSERVATION. Examine with a compound microscope, a small drop of blood taken from the finger by pricking it with a pin. Care must be taken to dilute it with a little water or saliva before putting on the cover glass,else the corpuscles will be too thick to be distinguishable. If the specimen is to be viewed for a considerable length of time, a little oil should be run around the edge of the cover glass to prevent evaporation. All of the corpuscles seen will generally be of the red kind, though occasional white ones may be found. These can be distinguished from the red by their greater size and transparency. On account of the small amount of coloring mat er in each one, the red corpuscles do not appear red under the microscope. Make a sketch of the corpuscles as they appear under the glass.

The Red Corpuscles have the same general structure as cells, but there is an absence of any nucleus. In shape they are thin disks with concave sides. In size they vary from 1-3500 to 1-3200 of inch in diameter. In healthy blood they are exceedingly numerous, there being estimated to be as many as five million in a small drop of blood The function of the red corpuscles is to act as *oxygen carriers.* They absorb oxygen from the air at the lungs and give it up to the different cells of the body. They are enabled to do this by the presence in them of a large proportion of a reddish coloring matter called

Haemoglobin. This substance has the remarkable property of forming a weak chemical union with oxygen and, after being united with it for a while, of giving it up to tissues which contain no oxygen. The haemoglobin also gives the red corpuscles their color. It is found attached to the wall of the corpuscle from which it may be separated, though slightly changed, by the following method:

Cover a well washed clot of blood in a vessel, with alcohol. With a glass rod or clean piece of wood, work the clot into as fine pieces as possible. Allow to stand over night. The clear reddish liquid contains the coloring matter that has been separated from the corpuscles. This may be poured off, without disturbing the bottom portion, and kept indefinitely in a well corked bottle.

Origin of Red Corpuscles. As the red corpuscles are constantly being destroyed in various ways, new ones have to be regularly supplied from some source to take their place. Their origin is not definitely known, though the best authorities now agree that a portion of them, at least, is formed in the red marrow of the bones.

White Corpuscles. These are irregular in shape and about three times as large as the red ones. They are much less numerous, there being only about one white corpuscle for every 300 red ones. They are identical with the pus cells which are found in sores. They are able to change their form and pass through the walls of the capillaries into the tissues. (Copy drawing.) There are several varieties of these corpuscles and their work, as now understood, is to purify the blood by destroying disease germs. They are formed chiefly in the lymphatic glands.

The Plasma consists of water with a great number of different substances dissolved in it. It is therefore, a very complex liquid. The following important constituents may be named: 1. The *fibrin factors* which, by changing into fibrin, cause the blood to coagulate. 2. Substances which serve as *food* for the cells. Chief among these are *serum albumen*, *fatty* substances, and *sugary* substances. 3. *Impurities* from the cells, most important of which, are *carbon dioxid* and *urea*. On account of the demands made upon the blood by the cells, the variety of foods eaten, and the discharge of impurities, the proportion of the constituents of the plasma is constantly changing.

The *serum* is that portion of the plasma which remains, after the separation of the fibrin factors. When does this separation occur?

The chief constituents of the blood are represented by the following table:

- Blood
  - Corpuscles
    - Red
    - White
  - Plasma
    - Serum ....
      - Water
      - Serum Albumen
      - Fatty Substances
      - Sugary Substances
      - Salts
        - Common Salt
        - Phosphate of Lime
        - Carbonate of Lime
      - Impurities
        - Carbon dioxid
        - Urea
    - Fibrin Factors

Systems which Work for the Blood. That the blood may preform its double work for the cells, requires the combined action of several systems. The *circulatory* system keeps it moving through all portions of the body. The *digestive* system supplies it with liquid food. The *respiratory* system supplies it with oxygen. The *excretory* system relieves it of its impurities. State the necessity for the work which is done by each of these systems.

References:

Review Questions. 1. What important work is accomplished in the body, through the agency of the blood and lymph? 2. Compare the physical properties of the blood with those of water. 3. How prove that oxygen changes blood from a dark red to a bright red color. 4. Name the principal constituents of the blood. Give use of each constituent. 5. What is hæmoglobin? What is it able to do? What use is made of it? 6. Give composition of the plasma. How does it differ from the serum? 7. What is fibrin? When and for what purpose is it formed? From what is it formed? How does it differ from fibrin factors? 8. Compare red and white corpuscles with reference to shape, size, number, origin, and function. 9. How may coagulation of the blood be hastened? How may it be prevented? 10. What are the different systems of the body which work for the blood?

Circulation of the Blood.

The blood is, above all, a *moving* liquid. Its regular motion through the body—starting at one place, flowing out to the different parts and returning to that place—is termed the circulation.

The discovery of the circulation of the blood was made in 1616 by a physician named Harvey. In 1619 he taught it in his public lectures and in 1628 published the proofs. No single discovery with reference to the human body has proved of so great importance. A knowledge of the nature and purpose of the circulation was the necessary first step toward a comprehension of the plan of maintaining life. Hence Physiology as a science dates from the time of Harvey's discovery.

The Necessity for the Circulation lies in the fact that the blood acts as a *carrier* for the cells. Oxygen from the lungs, and liquid food from the digestive organs, reach the cells through the blood. Likewise, the blood must convey the impurities from the cells to the organs of excretion. To accomplish these results the *blood must move*. So great is the necessity for the circulation that its stoppage, for only a brief interval of time, results in death.

The Organs of Circulation consist of a central force pump connected with a system of tubes which penetrate to all parts of the body. The force pump is called the *heart*, the tubes are called *blood vessels*. The blood vessels are of three kinds: *Arteries*, *veins*, and *capillaries*.

OBSERVATION. Procure from the butcher shop the heart of a sheep, calf, or hog. To insure the specimen against mutilation, the lungs and diaphragm must be ordered left attached to the heart. In studying the different parts, good results will be obtained by observing the following order of procedure: 1. Observe the connection of the heart to the lungs, diaphragm, and large blood vessels. Inflate the lungs and observe the position of the heart with reference to them. 3. Examine outside of pericardium. Then pierce its lower portion and collect the pericardial fluid. Increase the opening thus made until it is large enough to slip the heart out through it. Slide back the pericardium until its attachment to the large blood vessels above the heart is found. 3. Trace out for a short distance and study the veins and arteries now exposed. The arteries are to be distinguished by their thick walls which are elastic like rubber. The veins have thin walls which are inelastic. The heart may now be severed from the lungs by cutting the large blood vessels, care being taken to leave a considerable length of each attached to the heart. 4. Observe the outer portion of heart. The thick lower portion contains the cavities called VENTRICLES; the thin upper portion contains the AURICLES. The thicker and denser side lies toward the left of the animal's body and is called the LEFT side of the heart; the other is the RIGHT side. Locate the right auricle and the right ventricle; the left auricle and the left ventricle. 5. Make an incision into the right auricle large enough to see the inner portion. Observe muscular arrangement and inner surface. At the entrance into right ventricle find the TRICUSPID valve. 6. Lay open the right ventricle. Study tricuspid valve from the under side, noting its parts and tendinous attachments. Study muscular arrangement and lining of the ventricle. Compare thickness of walls with those of right auricle. Find the opening into pulmonary artery. 7. Split open this artery to where it enters the ventricle and find the RIGHT SEMI-LUNAR valve. Of how many parts is it composed? 8. In like manner dissect the left side of heart. Compare the auricle, ventricle, and valves, on this side, with similar parts on the right side of heart.

The Heart. By consulting some Physiology ascertain the shape, size, and location of the human heart. Name and describe its outer and inner coverings. Locate and name its cavities, valves, and the blood vessels connected with it. Copy drawing from chart, locating and naming parts. Practice on this drawing until you can reproduce it from memory. What is the special work of the auricles? Of the ventricles? Of the valves? Account for the fact that the walls of the ventricles are thicker than those of the auricles; that the walls of the left ventricle are thicker than those of the right.

How the Heart Does Its Work. The heart is a hollow muscle and does its work by contracting and relaxing. When it contracts its cavities are closed and the blood is forced from them. When it relaxes the cavities open and the blood flows in to refill them. Valves prevent the backward flow of blood. How? The heart's action may be readily illustrated in the following manner:

Fit valves into the two ends of a rubber tube, six inches long and an inch in diameter, so that they open in the same direction. The valves are easily prepared by burning or filing a smooth, round hole through each of two corks which just fit the tube. Place over the opening in each cork, a thin flap of rubber or leather and secure in position by pushing a pin through it into the cork. The valves thus formed may be inserted in the tube as directed. Now if the end of the tube containing the entrance valve, be placed in water and the body of the tube alternately compressed and released by the hand, water will flow up through it. What action of the ventricles is represented by compressing the sides of the tube? What by releasing the pressure?

By connecting the ends of the pump with rubber tubes which can be filled with water and connected with each other, the entire circulation may be illustrated.

Arteries and Veins. These are cylindrical tubes, connected with the heart, through which the blood passes. The arteries receive the blood from the ventricles and permit it to pass through them and their branches to all parts of the body. In its return to the heart the blood passes through the veins. Although arteries and veins are quite similar in structure they have some important differences. From some text on Physiology, ascertain how they differ with reference to thickness and elasticity of walls, the presence of valves, the kind of blood which they carry, and the nature of the flow of blood through them.

Through the elasticity of the arteries, the intermittent flow of blood, caused by the heart's action, is changed to a constant flow in the capillaries. When the ventricles contract and blood is forced into the arteries, they are filled over-full and have to swell out to make room for the excess. Then, while the ventricles are relaxing, the arteries exert their elastic force against the blood. The result is to keep the blood under constant pressure in the arteries and to cause it to flow steadily through the capillaries. The elasticity of the arteries is thus made to serve the same purpose in the circulation, as that served by the air chamber in force pumps

The purpose of the valves in the veins is to enable muscular contraction to assist in propelling the blood. When muscles contract they press against

the sides of the veins, passing through them, and tend to empty them at that place. Since the valves open in the direction of the flow of the blood, they will be closed by any backward motion. The force of muscular contraction is thus made to push the blood forward.

The Capillaries consist of a network of very fine blood vessels which connect the terminations of the smallest arteries with the beginning of the smallest veins. With a few exceptions, they penetrate and permeate all parts of the body. They differ from both arteries and veins in being very small and in having very thin walls. It is the function of the capillaries *to bring the blood as near as possible to the individual cells* so that the exchange of material between the blood and cells may readily take place. How is this exchange made easier by the small tubes and the thin walls?

OBSERVATION. With a compound microscope examine the flow of blood through the capillaries of the tail of a live tadpole. To hold the specimen in position and prevent its becoming too dry, attach it to the slide with a narrow strip of wet cloth, making several loose turns completely around both the specimen and slide. Care must be taken not to stop the circulation by too great pressure. A tadpole, recently caught and more than an inch in length, will give the best results. The observer will account for the seeming great rapidity of the moving stream by remembering that the microscope also magnifies the motion of the blood.

The Circulation Traced. The blood in making its double circuit passes through the circulatory organs in the following order: Right auricle, tricuspid valve, right ventricle, right semilunar valve, pulmonary arteries, capillaries of lungs, pulmonary veins, left auricle, mitral valve, left ventricle, left semilunar valve, aorta and branches, systemic capillaries, veins, vena cava ascending and descending, and then again into right auricle. At the lungs the blood gives up carbon dioxid and receives oxygen. In the systemic capillaries it gives up its oxygen and receives carbon dioxid and other impurities.

Divisions of Circulatory System. The circulation of the blood through the lungs is called the *pulmonary* circulation; through the body, the *systemic*; through the liver, the *portal*; through the kidneys, the *renal*; and through the heart itself, the *coronary* circulation.

Health Suggestions. The vigor of the circulatory organs is largely dependent upon one's habits of living. Perhaps no one thing benefits them more than regular physical exercise. Not only does muscular work assist in propelling blood through the veins, but is an important means of strengthening the heart's action as well. Violent exertions, on the other hand, endanger the circulatory organs and should be avoided. The effect of many stimulants, especially alcoholic drinks, is to interfere with the action of these organs and to diminish their vigor. Tight fitting clothing, on any part of the body, interferes with the free circulation and, for this reason, should not be worn.

References:

Review Questions. 1. What is accomplished in the body by the circulation of the blood? 2. Name the different kinds of circulatory organs and give use of each. 3. Draw a diagram of the heart, naming and locating the cavities, valves, and the large blood vessels connected with it. Indicate by arrows the direction of the flow of blood through the different parts. 4. Explain how the heart does its work. 5. Of what advantage is the elasticity of the arteries? 6. What purpose is served by the valves in the veins? 7. What is the special work of the capillaries? 8. Trace the blood from the right auricle, through the different circulatory organs, back to that place. 9. What causes the "pulse" in arteries? Why does the blood flow in spurts from a cut artery? 10. How are the organs of circulation affected by moderate physical exercise? How by excessive exercise? How by alcoholic drinks? 11. Give directions for stopping the flow of blood from wounds.

The Lymph and the Lymphatics.

The Lymph lies outside the capillary walls and fills up such spaces as exist between the cells of the different tissues and between the cells and the walls of the capillaries. The blood, it will be remembered, flows in closed tubes and does not come in direct contact with any of the tissues. Oxygen and liquid food pass from the blood through the lymph to get to the cells, while impurities from the cells pass through the lymph to get to the blood. The lymph is thus the medium through which the exchanges, between the blood and the cells, take place.

The Chief Source of the Lymph is the escape of the blood plasma at the capillaries. Partly on account of the pressure on the blood in the capillaries and partly on account of the natural tendency of liquids to pass through animal membranes, a considerable portion of the plasma penetrates the thin capillary walls and enters the spaces occupied by the lymph. Another source, of less importance, is the absorption of liquids from the alimentary canal. Liquids absorbed through the skin, on the outside of the body, also become a part of the lymph.

The Composition of the Lymph is quite similar to that of the blood. In fact, all the important constituents of the blood are found in the lymph, but in different proportions. Food materials for the cells and fibrin factors, exist in smaller proportions than in the blood; impurities from the cells, in larger proportions. The per cent of white corpuscles is slightly greater than in the blood, while there is nearly a complete absence of red corpuscles.

Physical Properties. The lymph is a colorless liquid slightly heavier and denser than water, though not so dense as the blood. It has no well defined odor or taste. Like the blood, it has the power of coagulating.

Movements of the Lymph. Though the lymph may be regarded as a comparatively quiet liquid, it has three well defined movements as follows: 1. A current which passes through it from the capillaries toward the cells. 2. A current from the cells toward the capillaries. 3. A movement of the entire body of lymph along the lymph channels, toward the larger lymph vessels.—The distinct and well defined lymph vessels are called the

Lymphatics. These vessels, though small, are exceedingly numerous in most parts of the body. Their walls are very thin and easily compressed, and all but the smallest are supplied with great numbers of valves. From the different organs of the body they gradually converge toward two main tubes. One of these, the *right lymphatic duct*, empties into the right subclavian vein. The other, the *thoracic duct*, empties into the left subclavian vein. (Copy drawing.) Lymph from the right side of the head, right arm, and right side of chest, passes into the blood through the right lymphatic duct. Lymph from the lower extremities, abdomen, left side of chest and head, and left arm, passes into the blood through the thoracic duct.

Functions of the Lymphatics. 1. They help enclose a quiet liquid (the lymph) which assists in the exchange of materials between the blood and the cells. 2. They return the plasma which escapes at the capillaries to make lymph, to the blood vessels. 3. They act as absorbing vessels in the skin and digestive organs, those absorbing from the small intestines being known as the *lacteals*.

Lymphatic Glands. Connected with the lymphatic vessels are great numbers of small glands, known as the lymphatic glands. As to the structure of these bodies and their connection with the lymphatics, there is a difference of opinion among physiologists. About all that can be said of their function is that they assist in the formation of white corpuscles.

Causes of Flow of Lymph. There is no force pump, like the heart, connected with the lymphatics and the causes of the flow of lymph are somewhat obscure. Blood pressure on the lymph at the capillaries and the contraction of muscles against the walls of the lymph vessels are supposed to be the chief causes. (Copy and explain drawing.)

References:

Review Questions. 1. What position, with reference to the capillaries and the cells, is occupied by the lymph? 2. What is the purpose of the lymph? 3. Compare the blood and the lymph with reference to composition, physical properties, and movement through the body. 4. Compare the lymphatics and the blood vessels with reference to size, number, and kinds. 5. What different purposes are served by the lymphatics? 6. How does muscular contraction cause the lymph to flow? 7. Trace the lymph, in its flow from the right hand, to where it enters the blood. Trace it from the feet to where it enters the blood. 8. What are lacteals? What purpose do they serve?

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Osmosis.

Osmosis, or *dialysis*, refers to the passage of liquid substances through animal membranes. If a vessel, with an upright membranous partition, be filled on one side with water containing salt, and on the other side with water containing sugar, an interchange of material will take place through the membrane until the same proportion of salt and sugar exists in the separated liquids.

EXPERIMENT. Separate the shell from the lining membrane, at one end of an egg, over an area, an inch in diameter. To do this without injuring the membrane, the shell must be broken into small pieces, which may be picked off with a pair of forceps. Fit a small glass tube, 8 inches long, into the other end, so that it shall penetrate the membrane and pass down into the yolk. Securely fasten the tube to the shell with beeswax, and set the egg in a small tumbler partly filled with water. Examine in the course of half an hour. What evidence now exists to prove that water has passed through the membrane into the egg? What to show that a portion of the egg has passed into the water? Which way has the flow of liquid been the greater?

The Conditions under which Osmosis occurs are as follows: 1. The liquids on the two sides of the membrane must be *unlike* either in composition or density. In case of a difference in density *the greater flow of liquid is toward the denser substance.* 2. Both liquids must be capable of wetting or penetrating the membrane. If but one liquid wets the membrane, the flow will take place in but one direction. 3. The liquids must have enough attraction for each other to mix readily.

Application. The many interchanges of material between different portions of the body are now understood to occur in accordance with the laws of osmosis. The exchange of material between the blood and the lymph, and the lymph and the cells; the exchange of gases at the lungs; and the absorption of liquids from the alimentary canal, furnish perhaps the best examples.

PROBLEM: Show what conditions must exist in order to cause a continuous flow of oxygen and food substances from the blood, through the lymph, to the cells; to cause a continuous flow of impurities in the opposite direction.

References:

Respiration.

Respiration, or breathing, is carried on by alternately taking air into and expelling it from the lungs. The former act is called *inspiration;* the latter *expiration.* Through respiration the blood is supplied with oxygen and relieved of certain impurities, principally carbon dioxid.

The Respiratory Organs consist of the air passages, respiratory muscles, and ribs, as shown by the following outline:

- Respiratory Organs
  - Air passages
    - Nostrils and mouth
    - Pharynx
    - Larynx
    - Trachea
    - Bronchi
    - Bronchial tubes
    - Lesser bronchial tubes
    - Air vesicles
  - Ribs
  - Muscles
    - Elevators of ribs
    - Intercostal...... External / Internal
    - Diaphragm

Observation. Secure from a butcher the lungs of a sheep, calf, or hog. The windpipe and heart should be left attached to the specimen, which must be kept in a moist condition until used. Study in the following order: 1. Examine the large open tube (trachea) and the closed tube lying back of it (oesophagus). Observe the cartilagenous rings in the trachea. What purpose do they serve? Remove one and make a drawing of it. 2. Insert a tube in the trachea and inflate the lungs. About how many times is their volume thus increased? 3. Examine the thin membrane (pleura) enclosing the lungs. Test its elasticity. 4. Sever the smallest lobe from the remainder by cutting the bronchial tube. Split this tube a short distance into the lung, observing its smooth lining and the openings of smaller tubes branching off from it. Are the rings in these tubes circular or like those in the trachea? Make cross sections of this portion of the lung and find the openings of the lesser bronchial tubes. 5. Follow the trachea down to where it branches to form the bronchi. Find a branch of the pulmonary artery which approaches one of the bronchi and cut both artery and bronchus from their connections. Now trace the bronchus and artery into the lung. Observe that as one branches, the other branches until the smallest divisions are reached. The pulmonary veins also lie alongside the bronchial tubes, but are not as easily traced as the arteries. Why? 6. Place a piece of lung upon water. In floating, what proportion of it is submerged. Inference.

The Air Passages form a continuous path for the entrance and exit of the air. By what kind of membrane are they lined? Name the different passages in the order that air goes through them, during inspiration: during expiration. The bronchial tubes, lesser bronchial tubes, and air vesicles, together with their connective tissue, blood vessels, lymphatics, nerves, and membranes, form the *lungs.* In order that the air may move freely through the different passages it is very necessary that they be kept *open* and *clean.*

Page 30 missing

The Air Passages are Kept Open by special contrivances found in their walls. In the trachea, bronchi, and larger bronchial tubes, these consist of imperfect cartilagenous rings. In the smaller tubes the rings disappear and their place is supplied by connective tissue. On account of the stiffening material in their walls, the size of the air tubes does not change as the air moves through them; but the air vesicles collapse when the air leaves them.

How the Air Passages are Kept Clean. This work is done by the cells which line the greater portion of the mucous membrane of the air passages, known as the *ciliated epithelial* cells. (Copy drawing of these cells from chart.) Extending into the air passages from the ends of these cells, are numerous hair-like projections called *cilia*. These keep up an inward and outward wave-like motion which has greater force in the *outward* direction. The effect of this motion is to carry any foreign matter to where it can be expelled from the passages. Even a slight cold on the lungs might prove fatal were it not for these cells. Why?

The Air Vesicles are the small membranous sacs found at the ends of the smallest bronchial tubes. They are about 1-100 of an inch in diameter and a cluster of them is found at the end of each bronchial tube. Each is composed of a lining of thin, flat cells, resting upon a delicate support of connective tissue which is very elastic. In these tiny sacs the air comes *nearest* the blood, giving up its oxygen and receiving carbon dioxid. But it does not come in direct contact with the blood. Within the walls of the vesicle is a network of capillaries, through which the blood flows. The exchange of gases takes place through the capillary walls. (Copy drawing.)

The Thorax is the air-tight cavity which contains the heart and lungs. It is enclosed on its different sides by the ribs and spinal column. It is separated from the abdomen by a strong muscular partition called the *diaphragm*. Between the ribs lie the *intercostal* muscles. By means of the diaphragm and the action of the intercostal muscles on the ribs, *the size of this cavity may be changed*. The thorax is lined with a thin, elastic membrane called the

Pleura. The pleura forms a double, closed sac, one side of which is attached to the lungs and the other to the chest walls. A thin membranous partition divides the thorax into two parts and the pleura surrounds the lungs so as to cause each half to hang in an air-tight sac. (Copy drawing.) It secretes a fluid which keeps it moist and prevents friction. What is pleurisy?

How Air is Brought into and Expelled from the Lungs. The atmosphere which surrounds us on every hand, exerts a pressure against objects of nearly 15 pounds to the square inch. It is this pressure which enables us to

breathe. Air enters and is expelled from the lungs for the same reason that it flows into and is forced out of a pair of bellows.

EXPERIMENT. Examine a pair of hand bellows, such as is used in kindling fires. If the sides are spread apart, the air flows into them: when they are pressed together, the air is forced out. Why? Spreading apart the sides of the bellows increases the space within and forms an area of less pressure than that on the outside. Air from the outside is then forced in, until the equality of the pressure is restored. When the sides of the bellows are forced together, the pressure within becomes greater than that on the outside. What then happens?

In breathing, the air-tight thorax takes the place of the bellows. By the action of the muscles its size is alternately increased and diminished. The lungs are suspended in the thorax with but a single opening—that through the trachea. What will happen when the thorax is enlarged? What, when it is diminished in size. Try the following

EXPERIMENT. With a tape line, take the circumference of the chest of a boy, when he has all the air possible expelled from the lungs. Take it again when he has them inflated to their utmost capacity. The difference in the measurements represents his relative chest capacity. What does this experiment show with reference to the cause of breathing?

How the Thorax Changes its Capacity. The capacity of the thorax *is increased* by the elevation of the ribs and the depression of the diaphragm. The former process increases the transverse diameter: the latter the longitudinal. The ribs are raised mainly by the action of muscles attached between them and the spinal column, called the *elevators* of the ribs, and by the *outer set* of *intercostal* muscles. The diaphragm being naturally in an arched position, it is depressed by its own contraction. As it lowers it pushes down the contents of the abdomen. Describe diaphragm.

EXPERIMENT. With five narrow strips of cardboard, one 8 inches long and the others 6 inches, construct a figure to represent the thorax. Let the long strip serve as the spinal column and one of the short ones as the breast bone. Fasten the others between them for ribs. The fastenings which must admit of motion, may be made by simply pushing pins through the strips where they join.

Holding the piece representing the spinal column in a vertical position, raise and lower the piece representing the breast bone. When is the space between the upright pieces the greatest? Apply to the action of the ribs in increasing the thoracic cavity.

The capacity of the thorax is *diminished* by lowering the ribs and elevating the diaphragm. Ordinarily the ribs are lowered by their own weight. In forced expiration the *internal intercostal* muscles are brought into play. The diaphragm is *pushed up* by the contents of the abdomen, which are pressed upon by the contraction of the abdominal walls. (Copy drawing from chart.)

Health Suggestions. One should breathe *pure air* in *sufficient* quantities. Pure air is, of course, found out of doors. It may be obtained indoors if attention is paid to the proper ventilation of rooms. The plan of heating a room will, to a large extent, determine the plan to be followed in ventilating it. In rooms where the air is not heated before being admitted, great care should be exercised to avoid drafts. For this reason, the air should be allowed to enter at several small openings instead of a few large ones.

PROBLEM: Suggest a plan for ventilating a school room, 50 ft. in length by 30 ft. in width, which has a stove near the middle and three windows on each side. In what kind of weather will the openings to admit air need to be large? When small? Why?

The *quantity* of air which one is able to breathe, is determined by his *chest capacity.* To keep this at its maximum, the following habits should be observed: 1. Take plenty of active exercise in the open air. 2. Practice occasional deep breathing. 3. Sit and stand erect with shoulders thrown back. 4. Wear loose fitting clothing around the *chest* and *waist.*

References:

Review Questions: 1. Of what two processes does respiration consist? 2. State the double purpose of respiration. 3. Name the air passages in the order that they are connected. 4. How are the air passages kept open? How are they kept clean? 5. Of what are the lungs composed? 6. Why are the lungs sometimes called "lights"? 7. Describe an air vesicle. What takes place in it? 8. What has atmospheric pressure to do with breathing? 9. Compare the action of the thorax to that of a pair of bellows. 10. How is the size of the thorax increased? How diminished? 11. Why are you unable to expand the chest when the mouth and nostrils are closed? Try it. 12. What causes the air in an occupied room to become impure? 13. What is meant by chest capacity? 14. Why will *active* exercise tend to increase the chest capacity? 15. How does compressing the waist diminish the chest capacity?

The Atmosphere.

The Atmosphere is tne gaseous envelope, surrounding the earth, in which we "live, move, and have our being." A slight knowledge of it is necessary, in the study of physiology, since a portion of it is consumed by the body in maintaining life. It is a mixture of colorless gases, nearly four-fifths being made up of nitrogen and one-fifth of oxygen. In addition to these it contains a small amount of carbon dioxid and a variable amount of watery vapor. We are especially concerned with oxygen and carbon dioxid, for by respiration, the former is given to the blood, and the latter removed from it.

The Gas Oxygen is remarkable for its strong attraction for other elements, especially carbon and hydrogen. On account of this attraction it unites readily with different substances to form compounds and is said to to bé a very active element. With certain substances it unites so rapidly that heat and light are given off. Tais rapid uniting we call burning or combustion.

Experiments. Prepare oxygen by heating together equal quantities of potassium chlorate and manganese dioxid For method of collecting the gas consult some text on chemistry. In the following experiments four large-mouthed bottles of gas are required. Care must be taken to keep the bottles closed, in order to prevent escape of the gas.

a. Insert a burning splinter in a bottle of oxygen and observe change in the color and size of the flame. Remove quickly and extinguish the flame, leaving only a spark on the end of the splinter. Insert a second time in the oxygen. The spark should burst into a flame.

b. Attach a piece of charcoal, or carbon, to the end of a wire. Hold in a hot flame until the carbon begins to glow and then insert in the oxygen. Leave there until the burning ceases. Observe that a portion of the carbon and all the oxygen has disappeared. What has become of them?

c. Remove the remaining carbon and pour some colorless lime water into the bottle. If mixed with the gas in the bottle by shaking, the lime water will turn a milky white color. This proves the presence of a new substance in the bottle. It is CARBON DIOXID and it has been formed by the UNITING of the carbon and the oxygen.

d. Bend a small loop on the end of a piece of picture wire. Heat the loop in a hot flame and then insert in some powdered sulphur. Ignite the melted sulphur which adheres and insert it quickly in a bottle of oxygen. Does the wire burn with a flame? Observe the dark brittle material which is formed. It is a compound of oxygen and iron, similar to iron rust, and has been formed by their uniting.

Purpose of Oxygen in the Body. The purpose of oxygen in the body is to produce *a continuous series of chemical changes* which shall liberate heat and supply the force with which the body does its work. It produces these changes by uniting with the different constituents of the liquid food in the cells and in some instances with the cells themselves, to form new substances. Since life depends directly on the continuance of these changes, oxygen is said to be the supporter of life.

The new materials which result from chemical unions in the cells are of two kinds: Those which can be used in cell growth, and those which form the waste and have to be removed. One of the most important waste materials thus formed is

Carbon Dioxid. This substance is formed by the union of oxygen with the carbon of the food materials in the body. It is a gas, heavier than air, which extinguishes flame and, in large quantities, is injurious to animal life. It is removed from the atmosphere by plants and serves an important purpose in their growth. The test for carbon dioxid is lime water with which it unites to form carbonate of lime.

EXPERIMENTS. Prepare lime water by stirring a small amount of FRESH lime in water and allowing it to settle. The clear liquid above the lime, is lime water. It may be poured off and used, while the vessel containing the lime may be filled again with water for future supplies.

a. Blow the breath through a small tube into lime water in a tumbler. The lime water turns a milky white color. What does this prove to be present in the breath?

b. Burn a splinter in a large bottle, keeping the top covered. Then pour in a little lime water and shake. Observe and account for the result.

c. Pour a little hydrochloric acid over some pieces of limestone in a bottle. A gas is liberated which fills the bottle. It is carbon dioxid. 1. Insert a burning splinter in the gas and observe the effect. 2. Tip the bottle over the mouth of a tumbler as you would to empty it of water, though not far enough to spill the acid. Now insert the burning splinter in the tumbler and account for what happens. What is proven with reference to the weight of the gas?

d. Fill a quart jar even full of water. Place a heavy piece of cardboard over its mouth and invert, without spilling, in a pan of water. Inserting a tube under the jar, blow air that has been held a short time in the lungs, into it. Remove the jar, when filled with air, from the pan, but keep the top well covered. 1. Insert a burning splinter and observe the result. This proves the absence of what? 2. Pour in a little lime water and shake. Account for the result.

e. Blow the breath against a cold window pane and account for the result. What does this show the breath to contain? Why must the window pane be cold?

References:

Review Questions. 1. What is the purpose of oxygen in the body? 2. How does it cause chemical changes? 3. Why are chemical changes necessary to life? 4. Why is oxygen so well adapted to producing chemical changes? 6. What is formed when oxygen unites with carbon? When it unites with iron? 6. Give some of the properties of carbon dioxid. What becomes of it after it escapes into the air? 7. What changes does the air undergo while in the lungs?

Digestion.

General Statement. Digestion is the process by which food material is prepared for the blood. Since nothing but liquids can enter the blood vessels, digestion must consist, to a large extent, in the reduction of solids to the liquid state. This is accomplished by *dissolving* them in certain liquids which are prepared for this purpose by organs called glands. Name one of these liquids and the glands which secrete it. With reference to the changes they have to undergo, during digestion, foods may be divided into three classes: 1. Substances already in the liquid state. Name one. These require no digestion, but are ready, at once, to be taken into the blood vessels. Oils and milk are exceptions to this class. 2. Foods which are soluble in water. Furnish examples. These require only to be dissolved. 3. Substances insoluble in water. The first step in the digestion of these is to change them into substances which are soluble in water. This class contains the greater number of our solid foods and includes albuminous substances, starches, and fats.

EXPERIMENT. Procure three tumblers. To the first add some water; to the second, a teaspoonful of fine salt; and to the third, some small pieces of limestone. Over the salt, in the second tumbler, pour some water, and over the limestone pour hydrochloric acid. Observe the effect in each case. What finally happens to both the solid substances?

As regards solubility, the substances in the tumblers will represent the three classes of food. The water, being a liquid, requires no change. The salt, a substance soluble in water, is readily dissolved by the water. The limestone, which is insoluble in water, is changed to a soluble substance which is dissolved by the water in the acid.

The Organs of Digestion are of three kinds: 1. Those for crushing and grinding the food. 2. Glands to secrete the liquids which act upon the food to change it chemically and dissolve it. 3. Cavities in which the different processes of digestion take place and tubes connecting them. The cavities and tubes are connected to form one continuous canal. This begins at the mouth and extends entirely through the body and is called the *alimentary canal*. The parts of this canal and the different glands are shown by the following table:

- Digestive Organs
  - Digestive Glands
    - Salivary . .
      - Parotid
      - Submaxillary
      - Sublingual
    - Gastric
    - Liver
    - Pancreas
    - Intestinal
  - Parts of Alimentary Canal
    - Mouth, containing
      - Teeth and
      - Tongue
    - Pharynx
    - Oesophagus
    - Stomach
    - Intestines . .
      - Small
        - Duodenum
        - Jejunum
        - Ileum
      - Large
        - Cœcum and Vermiform Appendix
        - Colon . .
          - Ascending
          - Transverse
          - Descending
        - Rectum

The Alimentary Canal, in different individuals, varies in length from 25 to 30 feet. The greater portion of it is made up of three distinct layers of substance called coats. (Copy drawing.) The œsophagus and the pharynx have only two coats. The inner coat consists of *mucous* membrane; the middle coat is *muscular;* the outer coat is a *serous* membrane, being a continuation of the lining of the abdominal cavity, called the *peritoneum.* Another coat is sometimes described, called the *submucous,* which lies between the mucous and muscular.

The Mucous Membrane, sometimes called the inner skin, is like the skin on the outside of the body in having two distinct layers of substance. The lower layer is the thicker and contains many blood vessels, nerves, and glands. The upper layer consists principally of tough non-sensitive epithelial cells. These protect the walls of the canal against the action of the digestive fluids. A fluid called mucus is secreted which keeps the membrane moist and soft. In different parts of the canal the mucous membrane presents different appearances. That of the mouth, pharynx, œsophagus, and large intestine is smooth. In the stomach it contains a number of longitudinal folds which greatly increase its surface and furnish additional room for the gastric glands embedded within it. In the small intestine it has a soft velvety appearance due to the presence of large numbers of absorbent vessels called the *villi,* and its surface is much increased by transverse folds or ridges. These retard the motion of the food through the small intestine and provide more surface for the villi.

Work of the Alimentary Muscles. The mechanical part of digestion is accomplished by muscles. These encircle the alimentary canal and, for the most part, form the middle coat. Around the mouth they are attached to the jaws and furnish the power for masticating the food. The *tongue* is a muscular organ which pushes the food around in the mouth during mastication and forces it back into the pharynx, when it is to be swallowed. The muscles of the pharynx and œsophagus force the food from the mouth into the stomach. Those of the stomach are arranged in three distinct layers which pass around it in different directions. By alternately contracting and relaxing they serve to mix the food with the gastric juice. How? Around the opening of the stomach into the duodenum, is a thick, muscular band which is contracted during stomach digestion, and is relaxed at other times. State its purpose. The muscles of the large and small intestines push the food along through the canal and finally force the undigested portions out of the body. The motions of the stomach and intestines caused by their muscles, are called the *peristaltic* movements. What muscles of the alimentary canal are voluntary? What are involuntary?

Parts of Alimentary Canal.—

Since information concerning the structure and function of the parts of the canal is easily obtained from the usual texts on Physiology, only the plan of their study is here indicated.

The Mouth is an irregular cavity at the beginning of the canal. Give three of its uses. Name its boundaries. How is it separated from the pharynx? How may its size be varied to suit its contents? Most of the space within the mouth is usually taken up by the tongue and

The Teeth. The parts of a tooth are *crown*, *neck*, and *fang*. Represent these parts by a drawing. A tooth is made up of *enamel*, *dentine*, *pulp*, and *cement*. Give properties and uses of each substance. Show by a drawing the position of each in the tooth. Name, locate, describe, and give use of the different kinds of teeth. What set of teeth is called permanent? What temporary? How many in each set? State two functions of the teeth. Give directions for care of teeth. When should the dentist be consulted?

The Tongue is a muscular organ which has its fibres running in every direction. It is thus able to assume a great variety of shapes. (Copy drawing.) At its base it is connected with hyoid and submaxillary bones. Name two uses of the tongue.

Pharynx. This cavity is the *cross roads* of the air tract and the food canal. It lies back of the mouth and has seven different openings. Name them. (Make drawing showing its position and connections.) How is it separated from the mouth? What is its work in swallowing? Are its muscles voluntary or involuntary?

Oesophagus. What is its length? With what is it connected? Describe its coats. Does the food fall from mouth into stomach, or is it forced down? Give proofs.

Stomach. Give its shape, size, location, openings, and coats. Describe its two orifices. Compare with other digestive cavities with reference to size. What glands does it contain? Where do they lie? Describe muscles of stomach? What is their function?

Small Intestine. Name and locate its parts. Give its length and diameter. What coats has it? Describe its mucous membrane. How is so long a tube able to accommodate itself to the cavity in which it lies? What is the *messentary?* What are its uses?

Large Intestine. Give its length and name its parts. At its beginning there is a sort of pouch, or sac, called the *coecum*, into which the small intestine empties by the *ileo-coecal valve*. At the bottom, the coecum extends into a very narrow projection called the *vermiform appendix* which is not only an organ without a function, but is often a source of disease. (Copy drawing showing connection of the coecum with the small intestine and appendix, naming the parts.)

Glands.—

Glands are found in many parts of the body, their function being to secrete liquids. The liquids, thus formed, serve different purposes, those of the digestive organs being to dissolve the food. The materials which form the liquids are obtained from the blood, but are supposed to undergo a change as they pass through the glands. The principal constituent of all the digestive fluids is water.

General Structure of Glands. All glands have the same essential parts. These are: 1. A layer of gland or secreting cells. 2. A thin layer of connective tissue, called the basement membrane. 3. A network of capillaries very near the cells. 4. A system of nerve fibres.—The gland cells are the active agents in secreting, the basement membrane furnishes a support for the cells, the capillaries bring a supply of blood near the cells, while the nerve fibres connect the cells with the nervous system which controls their activity.

The simplest arrangement of these parts is where the gland cells are spread over a smooth surface as shown in Fig. 1. Such an arrangement is called a *secreting surface.* It is employed where only a small amount of liquid is needed and there is a large amount of surface to furnish it. Name such a place. It cannot be employed where a large amount of liquid is needed. Fig. 2 shows a plan for increasing the secreting surface, by placing the gland cells in a tube, or sac shaped cavity. These are known as *simple tubular* or *simple sacular glands* according to the shape of the cavity. Fig. 3 shows how the secreting surface is still further increased by dividing the tubes and sacs into parts. In some cases the tubes and sacs branch and divide until a large mass, such as the liver or pancreas, is formed. It is then called a *compound* gland. It contains the same elements as the simple gland and only differs from it in the greater number of its branches. See Fig. 4. The compound glands are situated a small distance from the alimentary canal and the liquid they secrete is transferred to it by small tubes called *ducts.* (Copy drawings to show the different kinds of glands.)

The Digestive Glands are situated along the alimentary canal and into it they discharge their liquids. Within the canal the liquids come in direct contact with, and act upon, the food. Information concerning the location, structure, and secretions of these glands is easily obtained from the usual texts on Physiology.

Salivary Glands. Locate and describe the different kinds. Are they simple or compound? How do they differ in size? Which are affected by the mumps? When are they most active? How much saliva is secreted daily by them? Locate the ducts which convey the saliva to the mouth.

Gastric Glands. Where located? Number? Size? How much liquid do they secrete daily? What is it called? To what class of glands do they belong?

Liver. Give its location, size, color, and general structure. How much bile is secreted daily? The liver, unlike the other glands, is more or less active at all times and for this reason has a reservoir called the *gall bladder* which retains the bile until it is needed for digestive purposes In addition to assisting in digestion the liver removes certain impurities from the blood, and forms, from the materials which come to it through the portal vein, a sweetish substance called *glycogen.* "This is formed during digestion and is stored in the liver, to be gradually transformed, in the intervals of digestion, into grape sugar." In this way the liver stores the digested material until it is needed by the system.

Pancreas. Give its location, size, shape, and general structure. What is its secretion called? How much of this liquid is daily secreted? Where do the ducts from the liver and pancreas enter the intestine?

Intestinal Glands. These are embedded in the mucous membrane of both the small and large intestines and are, for the most part, simple tubular glands. What is their secretion called? How much is there of it?

How much liquid is secreted daily by all the digestive glands? How does this compare with the total amount of food consumed? What becomes of the excess of the liquids?

Digestive Processes.—

The different processes through which the food passes, in being reduced to the liquid state, are *mastication*, *insalivation*, *deglutition*, *stomach digestion*, and *intestinal digestion*.

Mastication. Of what does this process consist? By what organs is it accomplished? Why should it be performed slowly and thoroughly? One purpose of mastication is illustrated by the following

EXPERIMENT. Pulverize a teaspoonful of salt and place it in one of two tumblers. In the other, place the same amount of coarse salt. Add water until each tumbler is half full and observe in which the salt first dissolves. In which does the water come in contact with the greater surface of salt?

Since mastication helps reduce the food to a proper condition for swallowing and for the rapid action of the digestive fluids, it is to be regarded as a *preparatory* process.

Insalivation. This process consists in the mixing of the food with the saliva. How does it prepare the food for swallowing? How does it enable us to taste substances? Name two substances which are dissolved by the saliva. It acts on starch, changing it into *grape sugar*. What is the advantage of such a change? This action, however, is only temporary, as it is checked in the stomach by the acid of the gastric juice. The active agent in saliva is *ptyoline.*

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Deglutition, or swallowing, is the process by which food is transferred from the mouth to the stomach. How is it transferred from the mouth to the pharynx? From the pharynx to the stomach? Locate the muscles which do this work. How much of the swallowing process is voluntary?

Stomach Digestion is accomplished by the *gastric* juice. The most important active agents in this liquid are *hydrochloric* acid and *pepsin*. These act upon the *insoluble* nitrogenous food substances, called *proteids*, and change them into *soluble* substances called *peptones*. Why is this an important change? Good examples of nitrogenous food substances are the *albumen* of lean meat or the white of an egg, the *casein* of cheese, and the *legumen* of beans and peas. Fatty substances and starch are not digested in the stomach. At the beginning of stomach digestion, the muscle at the pyloric orifice is contracted, but as digestion proceeds it relaxes at intervals to let material pass into the small intestine. How is the food in the stomach mixed with the gastric juice? Stomach digestion may be illustrated by the following

EXPERIMENT. Prepare artificial gastric juice as follows: To a half tumblerful of water add 15 or 20 drops of hydrochloric acid. In this dissolve twice as much pepsin as will stay on the point of an average sized knife blade. (Both the pepsin and the acid are obtained from the drug store.) Place in the mixture the white of a hard-boiled egg, broken into very small pieces. Allow the whole to stand for 24 hours in a place where the temperature is about 98 deg. F. During this time portions of the egg will be dissolved.

Intestinal Digestion is accomplished mainly by the action of the bile and pancreatic juice. The *bile* has only a feeble action upon any of the food substances, but it helps along digestion, indirectly, in different ways. 1. It *counteracts* the acid of the stomach, giving the food an *alkaline* reaction which is necessary for the action of the pancreatic juice. 2. It increases the *peristaltic* action of the intestines by acting as a *stimulus* to the muscular coat. 3. It *retards the decomposition* of food in the intestines. 4. It furnishes a large bulk of liquid which serves to move the contents of the intestines readily along. What other functions has the liver than that of assisting in digestion?

The Pancreatic Juice is the most important of the digestive fluids and acts with vigor on *all* classes of foods. 1. It changes starch into grape sugar, completing the work begun by the saliva. 2. It changes proteids into peptones, finishing the work of the stomach. 3. It emulsifies the fats; that is, it breaks them up into very fine particles so that they can be absorbed. It also changes a portion of the fats into two soluble substances called *glycerine* and the *fatty acids*.

EXPERIMENT. To a little sweet oil in a test tube or small bottle add water and attempt to mix by shaking. Result. Then add a little baking soda and shake again. The oil is broken into very fine particles, forming what may be called an EMULSION.

Health Suggestions. Different physiologists have suggested the following rules with reference to the health of the digestive organs. Think

about them carefully and find some reason either for obeying or disobeying each one: 1. Eat slowly and masticate the food thoroughly. 2. Avoid eating between meals. 3. Avoid use of all stimulants, such as alcoholic drinks, tea, and coffee. 4. Take active exercise daily, in the open air. 5. Drink little water during meals, but plenty of water between meals. 6. Impure water should be boiled before drinking. 7. Eat only wholesome, well-cooked food. 8. Never swallow anything which is not thoroughly masticated. 9. Obey your appetite and do not think too much about what you eat and how you eat it.

Care of the Bowels. The undigested contents of the alimentary canal should be regularly discharged. When this is neglected a condition known as constipation or costiveness ensues. This is not only a source of great annoyance but is injurious to the health. In most instances it can be avoided by observing the following habits: 1. Have a regular time each day for evacuating the bowels. 2. Drink plenty of water between meals. 3. Eat generously of fruit and such coarse foods as oatmeal, corn bread, etc. Obstinate cases have been cured by simply eating a few mouthfuls of wheat bran each day. 4. Practice such exercises as bring the abdominal muscles into play and knead the abdomen with the hands.

Do not rely upon patent medicines, pills, etc., as they usually leave the canal in a weakened condition. When necessary consult a physician.

References:

Review Questions. 1. What is the purpose of digestion? 2. What kind of a process is it? 3. How do foods differ with reference to digestibility? 4. What are the three kinds of digestive organs? 5. Name the parts of the alimentary canal in their order. Describe its coats. 6. What different appearances does the mucous membrane present in different parts of the canal? 7. Describe the work of muscles in digestion. 8. Make a drawing of a tooth which will show the position of the materials which compose it. 9. Describe the tongue and name its uses. 10. Name the parts of a simple gland and give use of each part. 11. Show some of the plans for increasing the surface for secreting cells. 12. What is the principal constituent of all digestive fluids? 13. Give the different functions of the liver. 14. Why is the liver the only gland with a reservoir for its fluid? 15. Where, by what fluids, and in what manner are fat meat, the white of an egg, the starch of a potato, salt, and sugar digested?

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Absorption.

In general, absorption means the penetration of a liquid into the small spaces in the body of a solid. Applied to physiology, the term refers to the entrance of liquid materials into the blood vessels. The great source of liquid materials for the blood is the alimentary canal, and the study of absorption will therefore be confined to it.

To get from the canal into the blood vessels, the liquid materials must, in all instances, pass though membranous walls. This passage takes place according to the principle of osmosis. The liquid in the blood vessels, being *denser* than that in the alimentary canal, *the greater flow is toward the blood.* Within the walls of the canal are great numbers of capillaries and lymphatic vessels which receive the absorbed liquid materials.

The Capillaries throughout the entire length of the canal take in liquids, but the greater amount of their absorbing is done at the stomach and small intestines. The capillaries absorb *all kinds of liquid material except the emulsified fats.*

The Lymphatic Vessels are also capable of absorbing, to a small extent, from all parts of the canal, but all of their important work of this kind is confined to the small intestine. Here they have a remarkable development, forming a system of tubes peculiar to themselves, called

The Lacteals. The lacteals are *special absorbent vessels for the emulsified fats.* They have their beginnings in the small elevhtions of the mucous membrane of the small intestine, called the *villi.* (Copy drawing.) The different tubes comprising the lacteals run together, to form larger and larger ones in the mesentery, until they reach the thoracic duct. Whi e they have for their principal function the absortion of fats, they also, to a small extent, absorb other substances.

Two Routes. There are two distinct routes from the alimentary canal to the general circulation. If substances are absorbed by the blood vessels they pass through the portal vein to the liver. From there they go through the hepatic vein to the vena cava ascending, and then to the right auricle. If they are absorbed by the lacteals they pass to the thoracic duct and through it to the left subclavian vein, then into the vena cava descending, and into the right auricle. (Copy drawing showing these routes.)

Problem: Trace the digestion, absorption, and final entrance of lean meat, butter, starch, water, salt, and sugar into the general circulation.

References:

General Questions. 1. Give general meaning of the term absorption. What is its special meaning in physiology? 2. Why is the greater flow of liquids from the alimentary canal into the blood vessels and not the other way? 3. What materials are absorbed by the blood vessels? What by the lacteals? 4. What kind of absorbing vessels receive liquid materials from the stomach? What kinds from the small intestines? 5. What route is taken by the emulsified fat as it goes from the small intestines into the general circulation? What by the other materials?

Foods.

The different classes of foods are shown by the following table:

Foods	Organic	Proteids, or nitrogenous substances	Albumen
			Casein
			Gluten
			Legumen
		Non-nitrogenous substances	Oils and fats
			Starch
			Sugar
	Inorganic	Water	
		Salts	Common salt
			Phosphate of lime
			Carbonate of lime

Organic foods are those which have been formed in the bodies of animals and plants. The *inorganic* are furnished by the mineral kingdom. *Nitrogenous* substances are composed of carbon, hydrogen, oxygen, and nitrogen. The *non-nitrogenous* of carbon, hydrogen, and oxygen. *Albumen* is found in abundance in lean meat and in the white of eggs. *Casein* is found in milk and cheese. The sticky part of grain is *gluten*. Peas and beans are rich in *legumen* Name a food which contains fat. What foods contain oil? Name three foods rich in starch. Name three sugar producing plants.

Purposes of Food Food serves two distinct purposes in the body. 1. It provides material for the growth and repair of tissues. 2. It furnishes heat and force for the body. (Review topic on the growth of cells, page 5.)

Nearly all the tissues of the body contain nitrogen and therefore require nitrogenous food for their growth and repair. Animals fed on non-nitrogenous substances alone will starve. On the other hand the non-nitrogenous foods unite more readily with oxygen, and produce fewer impurities when they do unite, than the nitrogenous. For these reasons they are especially adapted to supplying heat and force.

The demand of the body for heat and force material, exceeds its demand for tissue material ordinarily by about "three to one." The nitrogenous and non-nitrogenous foods should therefore be eaten in about that proportion. Should this proportion ever vary?

Water cannot be classed as a true food, for it undergoes no change in the body. Yet it is probably the most important substance taken into the system. It is present in all tissues, and forms about two-thirds of the total weight of the body. A man weighing 150 pounds, if completely dried, would lose how much?

The main uses of water are: 1. To dissolve substances, so that they, as liquids, may move from place to place in the body. 2. To serve as a means of transfer of substances according to the principal of osmosis. It accomplishes this purpose by passing through membranes

and cell walls and carrying with it whatever it holds in solution. 3. It assists in the discharge of impurities from the body through the lungs, skin, and kidneys 4. It assists in the discharge of waste materials from the alimentary canal by keeping them in a soft condition.

The Salts serve various purposes in the body. Some added to water increase its dissolving power and are of use in the digestive fluids. Others become parts of tissues. Phosphate of lime is a constituent of both osseous and nervous tissue. The functions of others are unknown. Many have no function in the body and some even, are injurious.

References:

Questions. 1. Name an example of each of the different kinds of foods. 2. How do the organic foods differ in origin from the inorganic? 3. How do the nitrogenous foods differ in composition from the non-nitrogenous? 4. What two purposes are served in the body by foods? 5. Why are the nitrogenous foods sometimes called the "tissue builders?" 6. What must the food do in the cells in order to liberate heat and force? 7. Why are the non-nitrogenous food better adapted to supplying heat and force than the nitrogenous? 8. Account for the fact that people in cold climates eat large quantities of fat. 9. What is wrong with a bill of fare consisting of eggs, lean meat, beans, and rye bread? Suggest a better one.

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Excretion.

As a result of the chemical changes which take place in the cells, waste materials are constantly being formed. The waste materials which result from the uniting of oxygen with fatty, sugary, and starchy substances, are *carbon dioxid* and *water*. Those formed by the union of oxygen with nitrogenous substances are *carbon dioxid*, *water*, and *urea*. It is thus seen that there are only three waste materials formed in large quantities. Of these urea is the only one containing nitrogen. Only a small amount of the water discharged from the body is formed there. Its discharge in such large quantities is necessary to the removal of the other impurities. In addition to the waste substances already named there are quite a number, such as salts of different kinds, which are formed in small quantities.

From the cells, where they are formed, the waste materials find their way into the blood from which they are removed by the *Organs of Excretion*. These, named in the order of their importance, are the *kidneys*, *lungs*, *skin*, and *liver*.

The kidneys are two, bean shaped organs situated in the back and upper portion of the abdominal cavity, one on each side of the spinal

column. They weigh from 4 to 6 ounces each and lie between the abdominal wall and the peritoneum. Two large arteries from the aorta, called the *renal arteries*, supply them with blood, while they are connected with the vena cava ascending by the *renal veins*. They remove from the blood an exceedingly complex liquid called the *urine*, the principal constituents of which are *water*, *salts of different kinds*, and *urea*. The kidneys pass their secretion to the bladder by two slender tubes, called the *ureters*. (Copy Drawing.)

Minute Structure of the Kidneys. The inner substance of each kidney contains a great number of small tubes, called the *uriniferous tubes*, which penetrate it in all directions. Each of these tubes has its beginning in a cluster of fine capillaries which is surrounded by a membranous sheath, called the *capsule*. (Copy drawing.)

From the capsule each tube extends toward the hollow cavity on the inner side of the kidney, called the pelvis of the kidney. But before reaching that place it makes several turns upon itself and joins other tubes. A layer of *secreting epithelial* cells line the tubes and they are surrounded on the outside by a network of capillaries.

The Work of the Kidneys is divided between *the clusters of capillaries*, at the beginning of the tubes, and the *secreting* cells lining them. The former *separate water* and the *salts dissolved in it*, from the blood, while the latter *separate the urea*.

PROBLEM: Trace urea, water, and salts from the place where they are separated from the blood, through the different tubes, till they reach the bladder.

The Lungs have already been studied. They are the principal organs for removing carbon dioxid. They also remove small quantities of water and "animal matter." It is the last named impurity that gives air in poorly ventilated rooms its peculiar odor. How prove the presence of carbon dioxid in the breath? How show the presence of watery vapor?

PROBLEM: Trace carbon dioxid from the place where it is separated from the blood, through the different air passages, till it gets outside of the body.

The Skin is an organ with many functions and it will be more fully described at another place. Its excretory product is the *perspiration* or *sweat* which consists of water with a small amount of urea, common salt, and other substances dissolved in it. It is separated from the blood by the *sweat glands*. Find a description of these in some physiology. The perspiration comes from the skin either as a liquid or in the form of an invisible vapor. When a liquid it is called *sensible* perspiration; when a vapor, *insensible*.

EXPERIMENT. Lay the palm of the hand against a cold window pane for a short time. Account for the collection of moisture on the pane. Does this experiment illustrate sensible or insensible perspiration?

The work of the skin is quite similar to that of the kidneys. In reality it does on a small scale what the kidneys do on a large scale. When the kidneys are diseased the skin becomes more active. Why should it? Why should one bathe frequently?

The Liver discharges its impurities in the bile. This liquid has not been studied sufficiently to determine what portions of it are excrementitious and what portions assist in digestion.

References:

Review Questions. 1. How are impurities produced in the cells? 2. Name the organs of excretion in the order of their importance. What ones have other functions? 3. How do the impurities get from the cells to the organs of excretion? 4. Make a sketch of the kidneys, showing their connection with the large blood vessels and the bladder, naming parts. 5. In what do the uriniferous tubes have their beginning? In what do they terminate? With what are they lined? 6. Bright's disease of the kidneys affects the uriniferous tubes and interferes with their work. What impurity is then left in the blood? 7. What impurities are removed by the lungs? What by the skin?

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General Summary.

We have seen that the body is an aggregation of different kinds of cells; that it grows by the growth and reproduction of these cells; and that the life of the body, as a whole, is maintained by keeping these cells alive. We have also seen that the work of the systems, so far studied, is to take care of the different cells of the body. This they do by preparing, circulating, charging with oxygen, and keeping pure, a liquid (the blood) which supplies them with material necessary for their work, growth, and the carrying on of their vital processes. Answer carefully the following questions:

1. What purpose does oxygen serve in the cells? 2. How does it get from the atmosphere to the cells? 3. What different purposes does the liquid food serve in the cells? 4. How is the liquid food prepared? 5. How does it reach the cells? 6. What is the purpose of the blood? 7. Why must it circulate? 8. Name the principal waste materials formed in the cells. 9. Trace each from the cells to the excretory organs, and through them, to the outside of the body.

PROBLEMS: 1. Trace starch, fat, and albumen entirely through the body, telling what changes they undergo in digestion, by what routes they reach the general circulation, what purposes they serve in the cells, what impurities they form, and finally, how these impurities are removed from the body.

2. Write a sketch, of 200 words or less, setting forth the plan of maintaining life in the body.

Dissectional Review.

For this work the body of a cat is well adapted and usually obtainable. These directions therefore refer to the cat, though they may be applied to other small animals, such as the rabbit, squirrel, or rat.

The cat may be killed with chloroform in the following manner: Warm a small, tight box, having a close-fitting lid, by placing it near a stove or fire-place. Put the cat in the box and place on the lid, but leave a small opening, through which pour 3 or 4 tablespoonfuls of chloroform. Then close the opening and fasten down the lid. In about 12 minutes the cat will be dead.

Before the cat stiffens stretch it on a board by laying it on its back and driving a nail through each foot. The head should be drawn up and a tack driven through each ear into the board, to prevent the specimen's sagging in the center. Stand the board on end, in a slanting position, by a prop nailed at the back. This much of the work should be done an hour or so before the dissection is to begin. The teacher should also make a preliminary examination of the abdomen to see that it is in a fit condition for class study.

The following materials will be needed during the dissection and should be near at hand: A sharp knife with a good point, a pair of heavy scissors, a vessel of water, some cotton batting or a sponge, a bent glass tube for inflating the lungs, some fine cord, a few tacks, and a hammer.

During dissection, the specimen should be kept as clean as possible. The escaping blood should be mopped up with cotton or a damp sponge. Care must be taken not to cut into the stomach or intestines before the class. The teacher should make at least one dissection privately before attempting a class demonstration. The best results will be obtained by observing the order of work given below.

1. Cut through the abdominal wall in the center of the triangular space where the ribs converge. From here cut a slit downward to the lower portion of the abdomen and sideward, each way, as far as convenient. Tack the loosened abdominal walls to the board and proceed to study the exposed parts. Observe the muscles in the abdominal walls and the fold of the PERITONEUM which forms an apron-like covering over the intestines. Remove and study the LIVER. Note its color, shape, size, lobes, and reservoir for the bile. Find the STOMACH, PANCREAS, SPLEEN, and parts of the intestines. Observe their position and connections.

2. Tie the canal tightly in two places, half an inch apart above the stomach and cut it in two between these places. Likewise tie and cut the rectum. The stomach and intestines may now be removed from the abdominal cavity and studied to better advantage. Observe the position, shape, and attachment of the pancreas. Examine the MESENTERY and its connections with the intestines. Notice the divisions of the PORTAL VEIN and the LACTEALS passing through it. Tear the stomach and intestines from the mesentery and measure their length.

3. Examine the KIDNEYS and their connections. Observe that they lie back of the peritoneum. Find the tubes, the URETERS, which connect them to the bladder and RENAL artery and vein which connect each one to the aorta and vena cava ascending.

4. The THORAX may now be studied. Begin at the throat and slit the skin down to the abdomen. Then tear and cut it back to the shoulders. Examine the INTERCOSTAL muscles, between the ribs, and the DIAPHRAGM, below the thorax.

5. Cut into the throat until the TRACHEA is reached. Pull it out, cut it loose at the upper end, and insert a tube through which air may be blown into the lungs. Inflate the lungs, observing that the diaphragm moves downward while the ribs move outward and upward.

6. With a pair of scissors cut away one side of the thorax without injuring the diaphragm or lungs. Find a vertical, membranous partition, separating the thorax into two parts. This forms a part of the PLEURA. Inflate the lungs, a second time, to see how completely they fill out the thoracic cavity.

7. Cut away the remaining ribs and remove the lungs, windpipe, heart, and large blood vessels attached together. Inflate the lungs again, observing that they retain the shape of the thorax and completely surround the heart. Find the AORTA and test its elasticity.

8. Dissect the skin from around one side of the mouth and examine the SALIVARY glands. Cut the attachments of the lower jaw on one side, and press it down, so as to show the contents of the mouth and its connection with the PHARYNX.

The Osseous System.

The skeleton or frame work of the body is composed chiefly of osseous, cartilagenous, and connective tissues. What are the properties of each of these tissues? They are all concerned in the formation of the parts of the skeleton, known as the bones.

OBSERVATION. Study one of the long bones of the body of an animal, such as the femur. Test its hardness, strength, and stiffness. Saw it in two a third of the distance from one end and saw the short piece in two lengthwise. Compare the structure at different places. Find rough elevations on the outside for the attachment of muscles and small openings into the bone for the entrance of blood vessels and nerves.

Minute Structure of Bones. The *hardness* and *stiffness* of bones is given them by the *bone cells.* Bone cells differ from the other cells of the body in having very thick and hard cell walls which are composed principally of *carbonate* and *phosphate of lime.* These substances form what is known as the "mineral matter" of the bones. The bone cells are collected into small groups which are found in irregular shaped cavities called the *lecunae.* The *toughness* of the bone is caused by the presence of a large amount of "animal matter," principally connective tissue, which is mixed in with the bone cells. The proportion of the animal to the mineral matter of the bone is about two parts of the former to one of the latter.

EXPERIMENTS. 1. Soak a slender bone, like that in the leg of a chicken, over night in a mixture of one part of hydrochloric acid with four parts of water. The acid dissolves out the mineral matter. Ascertain by bending, stretching, and twisting what properties the bone has lost. What therefore are the properties given bone by the mineral matter?

2. Burn a small piece of bone in a clear gas flame or on a bed of coals until it ceases to blaze. Burning destroys the animal matter. By testing find what properties the bone has lost. What then are the properties given bone by the animal matter?

How Bone Cells are Nourished. They, like the other cells of the body, receive their nourishment from the blood. The blood reaches those within the bone through a great number of small canals which penetrate it in all directions. The largest of these are called the *Haversian canals.* (Named from Havers who discovered them.) Branching off from these, at right angles, are many smaller canals, called the *canaliculi.* These penetrate to the lecunae where the bone cells are found. (Copy drawing representing these canals.)

The cells at the surface of the bone get their nourishment from the blood vessels in the membrane surrounding the bone. What is it called?

Gross Structure of Bones. The gross structure of bones is best shown by a study of a single bone such as the femur. The two ends of this bone are capped by a layer of *elastic* cartilage while its entire surface is covered by a sheath of connective tissue, called the *periosteum.* In the central part is a long hollow portion, called the *marrow* cavity. This is lined with an inner sheath, the *endosteum*, and is filled with a fatty substance called the *yellow marrow.* Around the marrow cavity the bone is very dense and compact. At the ends the bone substance is coarse and spongy, containing a great

number of small cavities which are filled with the *red marrow*. What is the supposed function of the red marrow? (Copy drawing and name parts.)

Plan of the Skeleton. The central portion of the skeleton consists of the head and a faily rigid bony axis, called the *spinal column*. To the spinal column, all the other portions of the skeleton are either directly or indirectly attached. The ribs are directly attached, forming a framework for the breathing organs. Attached indirectly by two bony arches, the pelvic and shoulder girdles, are the two portions of the appendicular skeleton. To the shoulder girdle are attached the upper extremities, while the lower extremities are attached to the pelvic girdle. (Illustrate the plan of the skeleton by a drawing.)

The Names of the Principal Bones and their grouping in the body are shown by the following table:

I. **Axial Skeleton.**

A. Skull, 28.

1. Cranium, 8.
   - a. Frontal, forehead 1
   - b. Parietal 2
   - c. Temporals, temples.......2
   - d. Occipital 1
   - e. Sphenoid 1
   - f. Ethmoid................ 1
2. Face, 14.
   - a. Inferior Maxillary.... ...1
   - b. Superior Maxillaries......2
   - c. Palatine, palate..........2
   - d. Nasal bones.............2
   - e. Vomer....... 1
   - f. Inferior Turbinated..... 2
   - g. Lachrymals.. 2
   - h. Malars, cheek bones......2
3. Bones of the Ear, 6.
   - a. Malleus 2
   - b. Incus 2
   - c. Stapes....... 2

B. Spinal Column, 26.

1. Cervical, or neck vertebræ....7
2. Dorsal, or thoracic vertebræ.12
3. Lumbar vertebræ............5
4. Sacrum. 1
5. Coccyx 1

C. Thorax, 25.

1. Ribs 24
2. Sternum.... 1

D. Hyhoid, 1....................1

II. **Appendicular Skeleton.**

A. Shoulder Girdle, 4.

1. Clavicle, collar bone.........2
2. Scapula, shoulder blade......

B. Upper Extremities, 60.

1. Humerus 2
2. Radius 2
3. Ulna.......................2
4. Carpals, wrist bones........16
5. Metacarpals 10
6. Phalanges..................28

C. Pelvic Girdle, 2.

1. Os innominatum............2

D. Lower Extremities, 60.

1. Femur, thigh bone..........2
2. Tibia........... 2
3. Fibula......................2
4. Patella, knee cap...........2
5. Tarsals, ankle bones..... ..14
6. Metatarsals, bones of the in step 10
7. Phalanges, bones of the toes.28

Study the skeleton until you are, at least, able to locate and understand the uses of all the bones given in this list.

Size and Shape of Bones. The bones vary in shape and size to suit their position and use in the body. Some bones, like the humerus, are adapted to giving form, strength, and stiffness to parts of the body. Others, like the pelvic bones, are fitted for supporting and protecting. Others still, as the wrist and ear bones, are adapted, by their size and shape, to giving a peculiar kind of motion. Where is the smallest bone in the body? Where is the largest? Why should the skull bones and the ribs be flat? Why should the femur, and the humerus, be long and cylindrical? Why should the bones of the wrist be short and rounded?

The Bones as Instruments of Motion. The most important use of the bones is to serve as levers in the production of motion. A lever may be described as a stiff bar which is used in lifting weights. It is made to turn on a fixed point of support called the *fulcrum*. The force applied to the bar is called the *power* and that which is lifted is termed the *weight*. Levers are of three kinds, known as the *first* class, *second* class, and *third* class. The only difference between them is in the position of the power, weight, and fulcrum. In the *first class* the *fulcrum is between* the power and weight. In the *second class* the *weight is between* the fulcrum and the power. In the *third class* the *power is between* the fulcrum and weight. (Make drawings to illustrate the different kinds of levers.)

In the body the muscles furnish the power, a part of the body itself, or some object to be lifted, serves for the weight, and the fulcrum is generally at a joint. While all the different classes of levers are represented in the body, the majority of them belong to the third class. The special advantage of this class is that *the power by moving a short distance can move the weight a long distance*. The contraction of the longest muscles does not amount to more than two or three inches, yet they are able, by this form of lever, to make portions of the body move as many feet. Furnish illustrations of this fact. Find a representative of each of the three classes of levers, in the body.

Articulations.

Any place in the body where two or more bones are joined together is called an articulation. Articulations are of two kinds, known as the *movable* and the *immovable*. A great number of the latter are to be found in the skull where projections from one bone interlock with those of another, the tissue between being very thin. This kind of an articulation is called a *suture*. (Examine bones of a skull.)

A Joint is a *movable* articulation. It must be so constructed that the bones glide over each other easily and without friction. The parts of the bones which help to form joints, are smooth and are covered with a thick layer of cartilagenous tissue. This serves as an elastic cushion to deaden shocks. The cartilage is covered with the *synovial* membrane, the inner surface of which secretes the *synovial fluid*. What is the purpose of

this fluid? It is retained in the joint by the synovial membrane which surrounds the ends of the bones and extends from one to the other so as to form a closed sac. Is this a serous or a mucous membrane? Why? Strong bands of connective tissue, called ligaments join the bones together. Are these elastic or inelastic? Why should they be? The fibres of the ligaments are interwoven with the periosteum, making a very secure attachment. In some cases the ligaments form one continuous sheath around the joint, making what is called a *capsular* ligament. Furnish an example. (Make a drawing to show the parts of a joint. Practice on this until it can be made from memory.)

The Different Kinds of Joints are the *ball and socket*, the *hinge*, the *pivot*, and the *combination* joint. The *ball and socket* joint consists of a ball shaped end of bone which fits into a cup-shaped cavity, called a socket. Name examples. This joint admits of motion in what directions? In the *hinge* joint the bones are grooved and fit together something after the plan of a hinge. Name examples. Of what motion is it capable? The *pivot* joint is formed by one bone rotating or turning against another. Furnish examples. This joint admits of motion around a given axis. Where a joint combines the motion and structure of some of the above joints it may be called a *combination* joint. Furnish examples.

Questions on Hygiene. What is the danger of having children walk at too early an age? Why should children not sit on seats too high for their feet to reach the floor? Why is moderate exercise beneficial, and violent exercise injurious to the bones? How is a broken bone "set?" What is a sprain? What is a dislocation? Why must a sprain have careful treatment?

References:

Review Questions. 1. Of what three kinds of tissue is the skeleton composed? 2. Name and locate the bones of the cranium. 3. Name and locate those of the face. 4 Of what use are the ribs? 5. To what is the hardness of the bones due? 6. To what is their toughness due? 7. How separate the animal matter of a bone from the mineral matter? 8. How remove the mineral matter? 9. How does the blood penetrate to the bone cells within the bone? 10. Describe the gross structure of a bone. Illustrate with a drawing. 11. What is a lever? Describe the three different kinds. Name an example of each in the body. 12. What peculiar advantage has a lever of the third class? 13. In levers of this class will the force of the muscular contraction be greater or less than the weight of the substance lifted? 14. Name the parts of a joint and give the use of each part. 15. How is the synovial fluid kept in the joint? 16. How are the ligaments attached to the bones?

The Muscular System.

The muscular is the most abundant of the tissues, forming by weight more than one-half of the entire body. What important properties does it possess? What is its chief use in the body? Muscular tissue, in order to accomplish its purpose, is organized into groups, called muscles. How many muscles in the body?

Muscle Cells are among the largest in the body. They are of two kinds, known as the *voluntary* and the *involuntary*. Each *voluntary* cell is composed of a long sack—the cell wall—which is filled with muscle protoplasm, the contractile substance of the cell. The surface of this cell shows a great number of very fine lines, on account of which it is said to be striated or striped. Many are found connected with the ends of nerve fibres. *Involuntary* cells differ from the voluntary, in being spindle shaped and in having a smooth, instead of a striped, surface. It also has a well defined nucleus. (Copy drawing showing the two kinds of cells.)

Two Kinds of Muscles, known as the voluntary and involuntary, are built up from the two kinds of muscle cells. The *voluntary muscles*, which form the larger and more important class, are built up from voluntary cells. A study of the structure of these muscles shows the cells to be placed end to end, forming fine muscle threads or fibres. A number of these threads form a slender bundle, around which is placed a thin layer of connective tissue. These bundles are again bound into larger ones by bands of connective tissue, so that the entire muscle consists of *bundles of bundles* of muscular threads. The whole is surrounded by a single sheath of connective tissue, called the *perimysium*. At the ends the muscles are attached to *tendons* which connect them with the bones. The *involuntary* muscles are built up from involuntary cells. These are not arranged into bundles, but are interwoven with each other to form thin bands or sheets.

OBSERVATION. As an example of a voluntary muscle examine one, such as is found in the leg of a cat, rabbit, or chicken. Note color, shape, and outside covering. Observe how the perimysium grades into the tendon. Observe the properties of the tendon and trace it to the bone with which it is connected.

As an example of an involuntary muscle, examine the muscular coat of the stomach of a beef. A section may be cut out, washed, and prepared for class study. Compare its color, shape, covering, etc., with that of the voluntary muscle.

Differences Between Voluntary and Involuntary Muscles. 1. The voluntary muscles are under the control of the will; the involuntary are not. 2. Voluntary muscles are reddish in color, while the involuntary are light and pale. There are exceptions to this, the most notable being the heart. 3. The voluntary are usually attached to bones which they move as levers; the involuntary form bands around hollow cavities and tubes, such as the stomach and arteries. 4. The voluntary muscles contract and relax quickly; the involuntary contract and relax slowly.

Muscular Stimuli. The natural condition of a muscle is that of relaxation. *It is made to contract* by the action of something else upon it. That which acts upon a muscle to cause it to contract is called a *stimulus.* All the muscles of the body are controlled by the nervous system which furnishes a stimulus known as the *nervous impulse.* This originates in nerve centers and reaches the muscles through the nerves. It will receive further study in connection with the nervous system.

There are also other muscular stimuli. The muscles of the leg of a frog, recently killed, have been made to contract by touching them with hot or cold substances, by passing currents of electricity through them, by pricking or pinching them, and by the application of chemicals, such as acids, salts, etc. Heat and cold, electricity, mechanical irritation, and certain chemicals are therefore to be classed as muscular stimuli. None of these, however, are made use of in the body to cause muscles to contract.

What Happens When a Muscle Contracts. Careful experiments, upon the muscles of frogs, have proved that the following things occur when a muscle contracts: 1. The oxygen and certain food substances in the muscle are used up. 2. Waste materials such as carbon dioxid and urea are produced. 3. Heat is produced.

Blood Supply of Muscles. The rapid chemical changes in the muscles demand a large supply of blood, which shall furnish liquid food and oxygen and remove the waste. Blood vessels penetrate them in all directions and the capillaries lie very close to the individual cells. Provision is also made, through the nervous system, whereby the flow of blood in a muscle is increased when it is at work.

Muscular *fatigue* is supposed to be caused by the waste matter not being removed from the muscle as fast as it is formed.

Attachment to the Bones. The voluntary muscles are attached to the bones by tough strips of inelastic connective tissue, called *tendons.* Why should they be inelastic? The tendon is *interwoven with the periosteum of the bone* at one end and the *perimysium of the muscle* at the other, making firm and secure attachments. Name and locate the strongest tendon in the body.

Plan of Placing Muscles. The voluntary muscles are, in most cases, placed so as to work in opposition to each other. For example, one muscle will be placed so that its contraction will bend a joint, while another will be so placed that its contraction will straighten the same joint.

Muscles are classed, according to their position and use in the body, as follows: Flexors and extensors, adductors and abductors, rotators, radiating and sphincters. These are arranged in pairs. The *flexors* and *extensors* form a pair for bending and straightening joints; the *adductors* and *abductors,* for drawing the limbs toward the axis of the body and moving them away; the *rotators* (two kinds), for twisting and untwisting joints; the

radiating and *sphincters*, for opening and closing natural openings. Find examples of each of these different classes of muscles.

Work of the Involuntary Muscles. The motions of the body which are directly concerned in maintaining life are brought about by *involuntary* muscles. The most important of these are the contracting of the heart, and the motion of the respiratory and digestive organs. Why should such important motions be involuntary?

Effect of Muscular Contraction on the Circulation of the Blood. The veins contain many valves. Muscles contracting against the walls of the veins, close them up, forcing the blood out of them. The valves will then cause the blood to flow which way? As the muscles relax the veins are again filled by blood from the capillaries. In this way the muscles help force the blood from the capillaries back to the heart. This work of the muscles is considered by many physiologists as very important. How does muscular contraction cause the lymph to flow?

Necessity for Exercise. The hygiene of the muscular system may all be expressed in the one word "exercise." The fact that more than half the entire body, by weight, is muscular tissue, makes a certain amount of daily exercise imperative. If this is neglected the muscles begin a slow process of degeneration which results in their becoming weak, soft, and flabby. But the worst effects of neglected exercise, are to be observed on other portions of the body. The circulation is diminished in force, the blood loses large numbers of its red corpuscles, the breathing capacity is lessened, the excretion of waste is retarded, appetite fails, power to resist disease is diminished, and energy for both mental and physical work is lacking. In brief, the surest and easiest way to become a helpless invalid would be to cease from all physical exercise.

What *precautions* should be observed in taking exercise? Suggest forms of exercise suitable for the "brain worker." What kinds of exercise develop the lungs? How much should be taken daily?

References:

Review Questions. 1. Describe a voluntary muscle cell. 2. Show how the voluntary muscle is built up. 3. Describe an involuntary cell and show how the involuntary muscle is built up. 4. State four differences between voluntary and involuntary muscles. 5. How is the nervous system able to make the muscles contract? 6. Why should a muscle be well supplied with blood? Why should the supply be increased when the muscle works? 7. What different things happen in a contracting muscle? 8. What is the supposed cause of fatigue? 9. How is the tendon attached to the muscle and the bone? 10. Describe the plan of placing muscles with reference to joints. 11. What work of the body is performed by involuntary muscles? 12. How does muscular contraction assist in the circulation of the blood and lymph? 13. What happens to the muscles when insufficient exercise is taken? 14. How does a lack of exercise affect other portions of the body?

The Skin.

The skin is the outside covering of the body. It consists of two layers:—the *dermis*, or true skin, and the *epidermis*, or cuticle.

The Dermis is the under and thicker layer of skin and is made up mainly of a *dense network of connective tissue fibres.* This gives to the skin its toughness. Interwoven with the connective tissue, are numerous *small blood vessels*, *nerves*, *lymphatics*, *oil glands*, and *perspiratory glands.* State the purpose of the blood vessels. The nerves terminate in small bulb-shaped organs called *touch corpuscles*. Their office is to enable us to feel. The lymphatics are absorbent vessels. The oil, or sebacious, glands are situated by the roots of hairs. What is their purpose? Describe the structure of the perspiratory glands and give their function.

At its *outer* surface, the dermis is exceedingly rough and uneven, forming numerous elevations called the *papillae.* Each papilla contains the loop of a capillary vessel and a nerve fibre, and many of them are crowned with touch corpuscles. The inner surface of the dermis is attached to the parts beneath by a loose network of connective tissue fibres. (Copy drawing showing structure of the skin. Name parts.)

The Epidermis, or cuticle, is much thinner than the dermis. It is tough, non-sensitive, and, in some places, rough and hard. It contains no blood vessels, nerves, or lymphatics. Its purpose is purely protective.

Observation. Examine the cuticle of the hand. Where is it thickest? Account for the difference in thickness at different places. Pick a thick portion of it with a pin to see if pain is felt. Inference.

The cuticle grows by the multiplication of cells at its under surface, they receiving nourishment from blood vessels in the dermis. At this place the cells of the cuticle are full and round, while at the outer surface they are flat and scaly. Account for the difference. Where the cuticle joins the dermis is a layer of pigment, or color, cells which give the color to the skin. The *hair* and *nails* are modifications of the cuticle.

A Hair is a long, slender cylinder of epidermis. It grows from a kind of pit in the dermis, by the addition of cells to its inner end. Can the cutting of the hair have any effect upon the rapidity of its growth? Give uses of the hair.

The Nail is composed of a number of hard, flat epidermal cells. It grows in length by the addition of cells to its root; it grows in thickness by the addition of cells to its under surface. That part of the dermis from which the nail grows is called the *matrix*. Of what use are the nails? How may relief be obtained in case of a bruise under the nail?

Observation. Examine a finger nail. Is the front or back portion the thicker? Account for the difference. What is a proof that the nails are not sensitive?

Functions of the Skin. a. It serves as a protective covering for the body. Which portion is purely protective? b. It purifies the blood by removing waste matter through the perspiration. By what is this work accomplished? c. It is the organ of feeling. What portion of it can feel? d. It is able to absorb liquids. What part of it does this? e. It regulates the temperature of the body; i. e. it keeps the body from getting *too cold* or *too hot*.

How the Skin Regulates Temperature. It assists in keeping the body *warm* by acting as a poor conductor of heat and preventing its escape. It serves to *cool* the body in two ways:—1. By the radiation of heat from its surface as from a stove. 2. By the evaporation of the perspiration

EXPERIMENTS. 1. Wet the back of the hand with water and move it through the air to hasten evaporation. Observe that as the hand dries, a sensation of cold is felt. Repeat the experiment, using alcohol instead of water and noting difference in effect. Alcohol evaporates faster than water. 2. Wrap a thin layer of cotton around the bulb of a thermometer and wet the cotton with alcohol. Move through the air to hasten evaporation. Note fall of the mercury.

The above experiments prove the principle that a liquid, in changing to a gas, absorbs heat. The perspiration in evaporating, or changing from a liquid to a gas, absorbs heat from the body, making it cool.

The body demands a constant temperature of 98°F. If the temperature gets above this the perspiration becomes more abundant and an increased amount of blood is sent to the skin. If it tends to become too cool perspiration is lessened and the amount of blood in the skin is diminished. The blood supply to the skin is controlled by the nervous system.

The Hygiene of the Skin is nearly all included in the problems of keeping it warm and clean. It is kept warm by *clothing*. *Bathing* is the method of keeping it clean.

Hygienic clothing should be warm and loose fitting. Why are woolen fabrics to be preferred to cotton? Since the clothing next the skin becomes charged with impurities, it should be frequently changed.

One should bathe often enough *to keep the body clean*. This will depend upon the season, the occupation of the individual, and the nature and amount of the perspiration. As to the kind of bath to be taken and the precautions to be observed, no general directions can be given. These must be determined by the health and natural vigor of the bather. Care must be exercised at all times, however, in preventing too great exposure of the body, during the bath.

References:

General Questions. 1. Give position and relative thickness of the dermis and epidermis. 2. Compare them with reference to growth and nourishment. 3. Give the function of the different parts of the skin. 4. To what is the color of the skin due? 5. How is the color affected by sunlight? 6. How does the perspiration cool the body? 7. What different kinds of epidermis are found on our bodies? What kinds on the body of a chicken? 8. What precautions should be observed, by one in poor health, in bathing?

The Nervous System.

I. Elements of System.

Nervous Tissue is of two varieties. These, on account of their color, have been designated the "gray matter" and the "white matter." Both are soft, weak, inelastic, and, to the naked eye, appear as structureless masses. The microscope, however, shows them to be organized into cells which have long, thread-like attachments, called fibres.

The Nerve Cell has the usual parts of a complete cell (name them), but differs from all the other cells of the body in having its protoplasm extended, at one or more places, to form the central part of the nerve fibre. The nerve cells, however, in different parts of the body, differ greatly in size and shape. (Copy drawing of different kinds of nerve cells.)

They may exist singly, as in the touch corpuscles of the skin, but are usually found in groups, called the *ganglia*. What is a single group called? The brain and spinal cord are great collections of ganglia. A group of cells working together, for the *same* purpose, forms a *nerve center*.

The *function* of the nerve cell is to produce the *nervous force*, or *energy*, one form of which passes out through the fibres and is called the *nervous impulse*.

The Nerve Fibre is a slender filament or thread of nervous matter, leading off from the nerve cell and connecting it with some part of the body. Every fibre contains a central part which is a continuation of the protoplasm of the nerve cell and is called the *axis cylinder*. In most fibres the axis cylinder is surrounded by two other parts:—An outside coat, called the *primitive sheath*, and a middle layer of oily substance, called the *medullary sheath*. (Copy drawing.)

The *function* of the fibres is to *transmit*, or carry, nervous impulses. This work is done wholly by the axis cylinder, the purpose of the other two coats being to protect the axis cylinder and to prevent the escape of impulses from it.

The fibres are grouped together forming bundles, called *nerves*. Locate and name the largest nerve in the body. How large is it? About how many fibres does it contain? (Copy drawing.)

Relation of the Nerve Cell and Fibre. The nerve cell and fibre are now regarded as two parts of the same thing. In their growth, the cell forms first and the fibre grows out from it toward that with which it is to make connection. The "gray matter" appears to be the true nerve substance, being able both to originate and to transmit nervous energy. In the cells it predominates, giving them a grayish color. In most of the fibres the "white matter" is in excess, causing them to have a whitish appearance. What purpose does it serve?

The Nervous Impulse is the means employed by the nervous system in communicating with and controlling the different parts of the body. The nature of the impulse is not understood, though different theories have been advanced regarding it. The best authorities now look upon it as a sort of wave motion which is started in the nerve cell, by chemical action, and which travels out, through the protoplasm of the fibres, to the different parts of the body.

Impulses are best known by their effects. They are able both to throw muscles, glands, and nerve centers into action, and to check their activity. Impulses which throw inactive organs into action, or quicken the action of those already at work, are called *excitant* impulses. Those which check altogether. or diminish, the action of working organs are said to be *inhibitory*.

Connections of Nerve Fibres. One end of every nerve fibre is, of course, connected with *its own* nerve cell The other end will be connected with that part of the body into which the cell is to discharge its impulse. This may be an involuntary muscle, such as is found in the arteries, heart, or digestive organs. It may be in one of the many different kinds of glands or nerve centers. Then again it may find its way to one of the voluntary muscles. The different fibres are named according to their connections and the direction and nature of the impulses which they transmit.

The Different Kinds of Fibres are shown by the following table:

Nerve Fibres	Afferent	Sensory	
		Excito-motor	
	Efferent	Motor	Excitant
		Vaso-motor	Inhibitory
		Secretory	
	Intercentral	Excitant	
		Inhibitory	

Those fibres whose cells are located in special sense organs, at the *outside* of the body, and which convey impulses *inward* to central ganglia, are called *afferent* fibres. Those whose cells are located *within* the body and which carry impulses *outward* to muscles and glands are *efferent* fibres. Those which connect different ganglia within the body, are called *intercentral* or *commissural* fibres. Those afferent fibres whose impulses produce sensations (feeling, pain, sight, etc.) are called *sensory*; those, whose impulses stimulate nerve centers to send out efferent impulses to muscles, are called *excito-motor*.

Of the efferent fibres, those which go to muscles are called *motor*, those connected with arteries and control the flow of blood are the *vaso-motor*, and those going to glands to regulate the secretion of liquids are *secretory* fibres. *Excitant* fibres are those which convey excitant impulses: the *inhibitory* are those which transmit impulses by that name. (Copy drawing illustrating the different kinds of fibres.)

References:

Review Questions. 1. In what way do nerve cells differ from all the other cells of the body? 2. Where are nerve cells supposed to exist singly? 3. How does a ganglion differ from a nerve center? 4. What is the function of the nerve cell? 5. Describe the parts of a nerve fibre and give use of each part. What is a nerve? 6. Why is the "gray matter" supposed to be the true nerve substance? 7. Account for the grayish appearance of the nerve cells and the whitish appearance of the fibres. 8. What purpose is served in the body by the nervous impulse? What is the supposed nature of the impulse? 9. How do excitant differ from inhibitory impulses? 10. With what will *one* end of a fibre always be connected? With what different things may the *other* end connect? 11. What kind of fibres are called afferent? What kind efferent? What intercentral? 12. Show, by a drawing, the general plan of connecting fibres. Name the parts and place arrows to show direction of the impulses.

II. Divisions of the Nervous System.

There are two recognized divisions of the nervous system, known as the *Sympathetic System* and the *Cerebro-Spinal System*. Both these divisions are made up of cells and fibres and do their work through the agency of the nervous impulse. In both, for the most part, the cells are collected into ganglia, and the fibres into nerves. They differ chiefly in the arrangement and position of their ganglia, and in their special work in the body.

The Sympathetic System.

The Cells of this System are collected into small ganglia, which range in size from a pin-head to half an inch in diameter. They are situated in various parts of the body. The more important ones are to be found in *two chains* which are in front, and a little to each side, of the spinal column. (Copy drawing.) In addition to these ganglia, there are several in the heart, a few in the head, and many small ones scattered throughout the body.

Many nerves come from these different ganglia, forming in some places, a complex network, called a *plexus*. Of these the *cardiac plexus* in the heart and the *solar plexus* of the abdomen are the most important.

Connection of Sympathetic Fibres. Fibres from the sympathetic ganglia have been traced to the involuntary muscles of the alimentary canal, to the walls of arteries, to the spinal cord, and to the other sympathetic ganglia. The heart is well supplied with sympathetic fibres, part of which come from ganglia within it and part from ganglia situated elsewhere.

The Function of the Sympathetic System, as inferred from the distribution of its fibres, is to control the action of *involuntary* organs, especially *those concerned in the maintenance of life*. It cannot be stated definitely, however, that this is its exclusive function, as fibres from the cerebro-spinal system also go to these organs. From the close connection of the two systems, it is difficult to separate their functions. In many instances it is certain that they together control the same organ.

Cerebro-Spinal System.

The ganglia of this system help to form a connected mass of nervous matter known as the brain and spinal cord. Going out from these, are nerves which make connection with all parts of the body. Thus the brain and cord constitute the center of the cerebro-spinal system, the parts of which are shown by the following table:

- Cerebro-Spinal System
  - Central ganglia
    - Brain
      - Cerebrum
      - Cerebellum
      - Medulla oblongata
    - Spinal cord
  - Nerves
    - Cranial
    - Spinal.

General Composition and Structure of Brain and Cord. The greater portion of these organs is made up of nerve cells and fibres. Mixed in with these are blood vessels, lymphatics, and enough connective tissue to hold the parts together. The groups of cells have a grayish color while the fibrous portions are whitish. Why?

Protection of Brain and Cord. This is accomplished in three different ways: 1. By the bones which surround the cavities in which they lie. What bones are these? 2. By three membranes of connective tissue which envelop them. Find a description of the position and structure of these membranes in some physiology. 3. By a layer of liquid which completely surrounds them. This occupies the large spaces in the loose arachnoidal membrane and serves as a "watery cushion" for the brain and cord.—Why should the brain and cord be so carefully protected?

The Brain is that portion of the cerebro-spinal system which lies in the cranial cavity. From some physiology ascertain its relative size and weight, its general structure, and its divisions. Is it a double or single organ? Name its parts. (From a model of the brain, make a "side view" drawing, showing the position and relative size of each part. Practice on this until it can be made from memory.)

The Cerebrum forms about *seven-eighths* of the entire brain. In what portion of the cranial cavity does the cerebrum lie? Locate it with reference to your own head.

NOTE. If a pencil be placed over the ear and pressed down, all that portion of the brain lying above the pencil is cerebrum.

Locate the "gray matter" of the cerebrum. What portion of it is "white matter?" Of what are these "matters" composed? How is the surface for "gray matter" increased? What are the hemispheres? How are they joined?

At the base of the cerebrum are several paired masses of nerve cells. The two largest of these are called the *corpus striatum* and the *optic thalmus.*

Functions of Cerebrum. The cerebrum is *the organ of the mind* and *controls voluntary motion.* These functions are performed by its cells which are arranged into nerve centers. The centers which are concerned in mind activity are called the *psychic centers*; those controlling motion are called

the *motor centers.* The location of some of the most important of these centers has been discovered and mapped out, but the greater portion of the surface of the cerebrum is as yet "an unexplored country." (Copy drawing showing the centers which have been located.)

The Cerebellum. Ascertain from some physiology its size, location, and general structure. Give position of its gray and white matter? (Copy drawing to show these.) Describe its convolutions and compare with those of cerebrum. Numerous fibres connect the cerebellum with the cerebrum, medulla oblongata, and spinal cord.

The *function* of the cerebellum is not understood, but it would seem, from experiments upon lower animals, that it *assists the cerebrum* in *controlling voluntary* motion. Animals from which it has been removed are unable to *regulate* and *co-ordinate* their voluntary motions.

The Medulla Oblongata. Give its location, size, shape, and connections. Its gray and white matter have no definite arrangement, as in other parts of the brain, but the gray is scattered through the white in little bunches or clusters.

Function. The medulla is a conductor of impulses between the brain and cord and contains a number of important nerve centers. The most important of these are the centers which control breathing and are called the *respiratory centers.* Why will an injury to these produce almost instant death?

The Spinal Cord. Ascertain its length and diameter. Does it fill the entire spinal cavity? In what does it terminate at the upper end? In what at the lower end? Is it double or single? Give arrangement of its gray and white matter. (Copy drawing to show this arrangement.)

Functions of Cord. The spinal cord has two distinct functions: 1. It conducts impulses between the brain and the spinal nerves. 2. It controls a large number of the reflex actions of the body. Which of these functions is performed by the white matter of the cord? Which by the gray matter? Upon what do you base your conclusion?

Cerebro-Spinal Nerves. The brain and cord are connected with the different parts of the body by forty-three pairs of fibre bundles, called nerves. Those which connect with the brain are called *cranial* nerves and those connected with the cord, *spinal* nerves.

The fibres of the cerebro-spinal nerves consist of two important classes. One class comes from the special sense-organ cells of the skin, nose, eyes, ears, and tongue. They convey impulses toward the brain and cord. What are they called? The other class makes connection with muscles and glands and conducts impulses away from the brain and cord. What are they called?

The Cranial Nerves are numbered in the order in which they leave the brain. The pair that leaves farthest toward the front is called the *first* pair,

the next in order is the *second* pair, and so on for the others. The distribution and function of these nerves are shown by the following table:

Number.	Name.	Distribution.	Function.
First Pair.	Olfactory	Mucous membrane of nose..	Nerves of smell.
Second Pair....	Optic..............	Retina of the eye............	Nerves of sight.
3rd,4th,6th Pairs	Motores oculi.....	Muscles of the eye..	Control motion of eyes.
Fifth Pair.......	Trigeminal........	Skin of face, muscles of jaws, mucous membrane of mouth, and front of tongue	Sensory nerve of face, controls muscles of mastication, nerve of taste to front of tongue.
Seventh Pair...	Facial......... ...	Muscles of the face.........	Control muscles of expression.
Eighth Pair....	Auditory..........	Internal ear.......	Hearing.
Ninth Pair......	Glossopharyngeal	Back of tongue, muscles of pharynx.	Nerve of taste to back of tongue, controls muscles of pharynx.
Tenth Pair......	Pneumogastric...	Larynx,lungs,liver & stom'ch	Sensory and inhibitory.
Eleventh Pair..	Spinal Accessory.	Muscles of neck	Motion.
Twelfth Pair ...	Hypoglossal	Muscles of tongue.	Motion.

Which of the cranial nerves are purely afferent? Which contain only efferent fibres? Which contain both kinds?

The Spinal Nerves pass from the spinal cord through small openings in the spinal column. How many pairs of them? Each nerve joins the cord by two roots, the one toward the front being called the *anterior* root and the one toward the back, the *posterior* root. (Copy drawing.) The posterior root contains afferent fibres while the anterior root contains efferent fibres. What will be the direction of impulses in each of the two roots? With what organs are the efferent fibres probably connected? With what the afferent?

References:

Review Questions. 1. In what are the cerebro-spinal and sympathetic systems alike? How do they differ? 2. Describe the arrangement of the ganglia of the sympathetic system. To what organs are its nerves distributed? What is its supposed function? 3. Where are all the ganglia of the cerebro-spinal system to be found? 4. How do these ganglia communicate with the different parts of the body? 5 Give the arrangement of gray and white matter in the cerebrum, cerebellum, medulla oblongata, and spinal cord. 6. Give the functions of the cerebrum, cerebellum, medulla oblongata, and spinal cord. 7 How are the brain and cord protected? 8. Locate and describe the cauda equina. 9. Give the distribution and function of the fifth pair of nerves. 10. How do the posterior roots of the spinal nerves differ from the anterior roots?

III. Kinds of Nervous Action.

The different kinds of nervous action are shown by the following table:

- Nervous Action
  - Physical
    - Voluntary
    - Involuntary
      - Reflex
      - Automatic
  - Mental
    - Thinking, willing, etc.
    - Sensation

The Physical Activities of the nervous system pertain to the control of the different organs of the body. In order to control organs, the means must be provided both for throwing them into action and checking their activity. The means employed by the nervous system for doing these two things are the excitant and inhibitory impulses. These impulses, as said before, are produced in the cells of nerve centers and are transmitted to the different organs by nerve fibres.

The different classes of centers which control organs are the *voluntary* centers, the *reflex* centers, and the *automatic* centers. None of these centers are *self-exciting*, but they in turn, must be controlled. The means employed for this purpose is generally, though not always, the nervous impulse.

Voluntary Action is controlled by the voluntary centers. Where are they located? These centers are made to discharge their impulses by impulses which they receive from the psychic, or mind centers. Hence they are under the control of the *will*. The separate steps leading up to a voluntary action are about as follows: 1. A purely mental action, such as a wish or desire. 2. Stimulation of voluntary centers by a discharge of impulses from the psychic centers. 3. Sending out of impulses from the voluntary centers to the muscles. 4. Contraction of muscles.

Voluntary action is limited to the class of muscles known by that name.

Involuntary Action refers to those activities of the body which are *not* controlled by the mind. They comprise the work of both muscles and glands. To what classes of nervous action do they chiefly belong?

Reflex Action is caused by impulses from reflex action centers. The greater number of these centers are located in the medulla oblongata, spinal cord, and ganglia of the sympathetic system. They are stimulated to send out impulses, by impulses coming to them from *sense-organ cells*. What are sense organs? Since the action is in the direction from which the exciting impulses come, it is called *reflex*, which means a *bending-back*.

Experiment. Remove the head from a live frog, checking the flow of blood with a little cotton. Place on a board and irritate a toe by pressure or by pricking with a pin. Observe and account for the frog's movements. Place a drop of acid on the frog's back and observe the result. What is the positive evidence that the frog's actions are not voluntary?

The different steps in the production of a reflex action are: 1. Strong stimulation of sense organ cells on the outside of the body. 2. Excitation of reflex centers by the impulses from the sense-organ cells. 3. Sending out

of impulses from the reflex centers to the muscles. 4. Contraction of muscles. (Copy drawing showing path of the impulses.)

The experiment with the frog shows that *voluntary* muscles may also be made to act reflexively. This occurs when the impulses from the sense-organ cells are of an *unusual* order. Furnish illustrations.

PROBLEM: Trace the nervous impulses which cause a burnt finger to be removed from danger before the mind knows it is hurt.

Automatic Action is that which is caused by impulses from automatic centers. These when stimulated send out impulses at *regular intervals*, causing a repetition of action. The term automatic means *self*-acting. In the production of this kind of action, the organs concerned are usually so connected that they are able to stimulate each other. They form, as it were, a sort of system which, when started, works independently of other portions of the nervous system. (See nervous control of heart, p. 100.) Some of the automatic centers are stimulated by other means than the nervous impulse.

Automatic actions may be divided into two classes—the *natural* and the *acquired*. A good example of the former is the beating of the heart: of the latter, walking. In acquired action the mind exerts a controlling influence, being able to throw given automatic systems into action, and to check entirely, or change their rate of action. To what extent is walking controlled by the mind?

Mental Action in its many phases is not understood. It is known, however, to be due to some form of activity of the psychic centers in the cerebrum. The method by which outside influences are able to affect some of these centers is understood and will be studied in connection with the sensations.

References:

Questions. 1. What means is employed by the nervous system in controlling the different parts of the body? 2. How are voluntary centers made to discharge their impulses? 3. Give the different steps in the production of a voluntary action. 4. Locate the reflex centers. How are they stimulated? 5. Give the different steps in the production of a reflex action. 6. Draw a diagram to show the course of the impulses, in the production of a reflex action. 7. What is the peculiarity of automatic centers? 8. What comprises an automatic system? 9. How may automatic actions be acquired? 10. Show that automatic actions are great labor saving contrivances.

IV. Nervous Control of Important Processes.

Control of the Blood Supply. The most important factor in the supplying of blood to the different organs of the body, is the force and rapidity of the heart's contractions. Let us see how these contractions are made to correspond with the needs of the body. In the first place, the heart has a small nervous system of its own, composed of sympathetic ganglia. Impulses from these are able to keep up its continued contractions but are unable either to increase or diminish the heart's motion.

The heart is connected with other parts of the nervous system by three kinds of nerve fibres: 1. A set of *sensory* fibres connect with the medulla oblongata and report the condition of the heart to the nerve centers located there. 2. A set of *inhibitory* fibres also connect with the medulla oblongata, but these carry impulses to the heart to *slow* its motion. 3. A set of *excitant* fibres which connect with the sympathetic system and bring impulses to the heart to *quicken* its motion. Impulses from the medulla oblongata and the sympathetic system are thus able to *regulate* the heart's action. (Copy drawing from the chart and study it in connection with the above description.) If there should be a greater demand than usual for blood over the body, how will the heart be made to beat faster? After the extra demand has ceased, how will the heart be made to beat slower?

All the heart can do by its contractions is to keep up the requisite amount of blood pressure in the arteries. It is unable to send a greater amount of blood to one organ than to another. But we know that organs when active receive more blood than when inactive. How is this accomplished? If the walls of the arteries be examined they are found to contain *bands of muscular tissue*. These bands are thickest where the arteries enter organs and are naturally in a *moderate state of contraction*. Should an organ need more than the usual amount of blood, *inhibitory* impulses go to the muscular walls of its arteries, causing them to relax. How will this increase the amount of blood which enters the organ? If it is desirable to decrease the blood supply to a certain organ, *excitant* impulses cause the muscular walls to contract. How will this diminish the amount of blood going to that organ? Account for the fact that violent exercise makes the face first pale and then red. During hard study where is the excess of blood needed? How is it obtained?

Control of Respiration. Sensory fibres extend from all parts of the mucous membrane, lining the air passages, to the medulla oblongata. These report the condition of the air passages to that part of the medulla known as the *respiratory* centers. From here one set of *excitant* fibres go to the diaphragm, another to the intercostal muscles, and another set to the abdominal muscles. Impulses from these produce the requisite contraction of muscles to cause the alternate expansion and contraction of the thorax. (Copy and study the drawing.)

The respiratory centers are generally stimulated *by the blood* which passes through them. If the blood contains a *small amount of oxygen* it causes the centers to send out impulses to *increase* the respiratory acts. If it contains a *large amount of oxygen*, the impulses are *less* in strength. This explains how physical exercise is able to increase the force and rapidity of the respiratory acts. The muscles, at work, consume large quantities of oxygen and give carbon dioxid to the blood. In this way they get the blood in such a condition that it can act strongly upon the respiratory centers.

The respiratory centers may also be stimulated in other ways. Should a foreign substance get into the larynx, violent coughing results. This is caused by nerve cells in the mucous membrane, discharging impulses to the respiratory centers, which stimulate them to send out impulses to the respiratory muscles. In like manner an irritation of the mucous membrane of the nostrils causes sneezing. It is thus seen that the respiratory centers may be made to act *reflexively* by impulses from sense-organ cells.

Voluntary centers in the brain are also able to stimulate the respiratory centers and make them act under the direction of the will. Furnish illustrations of this fact.

Control of Digestive Processes. Sensory fibres leave the mucous membrane at all points along the alimentary canal and connect with nerve centers situated in the brain, spinal cord, and sympathetic ganglia. These make known the condition of the canal at the different centers. From these centers fibres go *to the glands* which supply the digestive fluids, *to the muscles* which are concerned in digestion, and *to the walls of the arteries* which supply the blood to the various digestive organs.

The food pressing against the mucous membrane, causes a discharge of impulses to the different nerve centers and these, in turn, stimulate the organs with which they are connected. By this arrangement the food itself causes that work to be done which is necessary for its digestion. Show how the presence of food in the stomach causes the flow of the gastric juice? How will the presence of food in the pharynx induce swallowing? (Copy drawing.)

References:

Questions. 1. What kind of nervous action is illustrated by the heart? 2. What is the special work of the ganglia within the heart? 3. How is the heart's motion quickened? How is it slowed? 4. How is the flow of blood through the arteries regulated? 5. How is the flow of blood through the respiratory centers able to regulate the force and rapidity of the respiratory acts? 6. Of what advantage is it to have the respiratory centers controlled by strong impulses from the mucous membrane of the air passages? 7. Of what advantage, to have them partly under control of the will? 8. To what class of nervous actions do those of digestion belong? 9. How does the presence of food in the mouth cause a flow of the saliva?

V. Sensations.

We have already noticed the existence of a large class of nerve fibres which are connected with nerve cells at the outside of the body and which conduct impulses inward to nerve centers. What are these fibres called? What effect do their impulses have upon reflex centers? These impulses when they reach the brain stimulate certain of the psychic centers, causing them to produce what we call a *feeling* or *sensation*. A sensation then *is an activity of the psychic centers caused by afferent impulses.*

The purpose of all sensation is to give the mind information. Intelligent action makes it necessary for the mind to know the condition of the body itself and also the physical conditions which surround it. Sensations are therefore of two kinds—*general* and *special*.

General Sensations are caused by impulses coming from many parts of the body, but which, so far as known, do not originate in nerve cells designed for that purpose. They seem rather to result from a general condition of the nervous system. As examples of general sensations may be mentioned *hunger, thirst, nausea, pain*, and the feelings of *comfort* and *discomfort*. Of what value are the feelings of hunger and thirst? What is the value of pain to the body?

Special Sensations are caused by impulses which come from definite places at the surface of the body, called the *special sense organs*. There are at least six different kinds of special sense organs, the sensations which they cause being known as the *special senses*. These are as follows: sight, hearing, smell, taste, touch, and temperature. What is the general purpose of the special sensations?

Every special sense apparatus has the following parts: 1. Sense-organ cells to originate the impulses. 2. Nerve fibres to transmit the impulses. 3. Nerve centers which receive the impulses and give rise to the sensation.

Each sense organ is capable of being stimulated by a single form of energy. This is known as the *stimulus* for that sense organ. For example, the sense organ cells of sight are made to discharge their impulses by the action of light. Light then is their stimulus. Furnish other illustrations.

Touch is the simplest of the special senses. Its sense-organ cells are located in the touch corpuscles of the skin. Their stimulus is ordinary *pressure*. When pressure is applied to the skin the sense-organ cells produce their impulses which, when transmitted to the brain, cause an activity of the psychic centers, called the touch sensation. At what places on the body is the sense of touch best developed?

EXPERIMENT. Place the points of a pair of dividers against the skin, on the back of the hand, of one who has been instructed to look in the opposite direction. Is one point felt or two? Repeat several times changing the distance between the points until it is fully determined how near together they must be, to be felt as one. In like manner test other parts of the body, as tips of fingers and back of neck. From a comparison of results, determine what portion of the body tested is most sensitive.

The Temperature Sense. It was at one time supposed that the touch corpuscles were also stimulated by heat and cold, but it is now known that there are special sense-organ cells for temperature. When the temperature of objects near the skin is the same as the skin, no sensations are produced. But when their temperature is above or below that of the skin, the temperature cells are made to discharge impulses.

Recent investigation proves the sense-organ cells of temperature to be of two kinds—one kind stimulated by heat, the other by cold.

"If a metal point, lightly weighted, be slowly and evenly moved over the skin, it gives rise to sensations of touch at some places and sensations of temperature at others. If it be a little warmer than the skin, at certain places it causes a sensation of heat. If it be colder than the skin, it gives rise to a sensation of cold as it travels over some places. The "cold sensation" spots are different from the "warm sensation" spots and are constant in the same individual from day to day."—Martin's Human Body.

The Sense of Taste. The sense-organ cells of taste are scattered over the upper surface of the tongue and perhaps the lower portion of the soft palate. They are found in little bulb-shaped organs called the taste bulbs. (Copy drawing.) Name and locate the different kinds of taste bulbs. The inner ends of these cells connect with fibres which join the nerves of taste. The stimulus for the sense-organ cells of taste are substances in the *liquid* state. Solid substances, to be tasted, must first be dissolved.

Little is known of the manner by which the different tastes are produced. The different kinds recognized are sweet, sour, bitter, salty, and alkaline. Flavors, such as vanilla and lemon, and the flavors of meats and fruits are really smelled, not tasted. Of what use is the sense of taste?

The Sense of Smell. The sense-organ cells of smell are located in the mucous membrane of the nasal passages. These cells are stimulated to discharge their impulses by the passage of odors through the nostrils. The mucous membrane of the nose also contains ciliated cells and touch corpuscles. The latter make it sensitive to the contact of foreign bodies. The olfactory, or smelling cells, are wedged in between the ciliated cells, with one end touching the surface of the membrane and the other end connected with fibres which transmit the impulses to the brain.

In order to smell, the odor *must be in motion* through the nostrils, and must come in direct contact with the olfactory cells. Of what use is the sense of smell? Describe the nerves of smell.

References:

Questions. 1. What is a sensation? Where and by what is it caused? 2. How do general differ from special sensations? 3. Name three examples of general sensations. Name all the special sensations. 4. What is a special sense stimulus? Give an example. 5. What is the general purpose of general sensations? What of special sensations? 6. What are the essential parts of a special sense apparatus? 7. What different things must happen in order to produce the sensation of touch? 8. By what are the sense-organ cells of temperature stimulated? 9. What three kinds of sense-organ cells are found in the skin? Name the stimulus for each. 10. What kind of substances can be tasted? What kind smelled?

Sound and the Sense of Hearing.

Sound is a form of vibration which is capable of affecting the organ of hearing. It originates in vibrating bodies.

EXPERIMENTS. 1. Strike a bell an easy blow and hold against its side some light substance, as a pith ball attached to a thread. Account for the movements of the light substance. 2. Sound a tuning fork by plucking, or striking it against the table. Its vibrations can be felt. If it is a large fork they can be seen. Place the vibrating prongs in water. Observe and account for the result.

All sound producing bodies are known to be in a state of vibration at the time of giving out sound. Account for the production of sound by the violin, organ, piano, flute, and jews-harp. All vibrations, however, are not sound, but only those that are more rapid than 16 per second and less rapid than 40,000 per second. Vibrations whose rate is less than 16, or more than 40,000 per second, are not appreciated by the organ of hearing.

How Sounds Differ. Sounds differ in *pitch*, *intensity*, and *quality*. By pitch is meant the height of a sound. It depends upon the *rapidity of vibrations*. By intensity is meant the energy of the vibration. It is nearly expressed by the word loudness. It depends upon the *amplitude*, or *width*, *of the vibrations*. Quality is that peculiarity of sound which enables us to distinguish one sound from another having the same pitch and intensity.

EXPERIMENTS. 1. Draw the edge of a visiting card over the teeth of a comb. The sound produced from each separate tooth may be considered a vibration. Account for the fact that a slow motion produces a tone of low pitch and a rapid one, a tone of high pitch. 2. With a violin or guitar show how pitch is affected by the length, tension, and size of the strings. 3. Show by plucking a string of a guitar, first lightly and then forcibly, that the loudness of the sound depends upon the amplitude of its vibrations.

Sound Vibrations may be transmitted, or carried, from where they originate to other places by *all* elastic substances. The atmosphere, however, since it presses in close against vibrating bodies and is in sufficient abundance to form a connecting medium between all things on the earth, is the most important transmitter of sound. Vibrating bodies set the air in contact with them into vibration. These vibrations pass through the air in the form of waves, called *sound waves*. When sound waves strike against *delicately poised* substances they set them into vibration.

EXPERIMENT. Wave a flat stiff body, such as a chart or board, back and forth through the air, in front of, and about ten feet away from, a large sheet of paper which is held loosely by its upper corners. The moving object imparts its motion to the air and the air transmits it to the paper, causing it to vibrate. Apply the principles involved in this experiment to the origin, transmission, and effect of sound waves.

Sound Waves are not made up of crests and troughs, like the waves on water, but are composed of condensed and rarefied portions. The condensed portion is formed when the vibrating body moves toward the air and the rarefied portion when it recedes from it. The length of a sound wave is the distance across one condensed portion and one rarefied portion. Sound waves vary in length from a few inches to several feet.

Sound waves sustain a very important relation to the subject of physiology. By means of them, man, in common with most animals, becomes acquainted with a certain condition of surrounding objects and is able to communicate with his fellows. The body, therefore, is supplied with a contrivance for producing sound vibrations and also a contrivance, by means of which, they are able to stimulate a part of the brain and produce the sensation of hearing. Name and locate these contrivances.

The Organ of the Voice. In the middle part of the larynx the air passage is much narrowed by two pairs of folds in the mucous membrane. These are the *vocal cords*, the lower pair being called the *true cords* and the upper pair the *false cords.* In the lower cords are ligaments and muscles which connect with the cartilagenous walls of the larynx. (See description of larynx in some physiology.) The pieces of cartilage, by changing the shape of the larynx, are able either to stretch or loosen the cords. When it is desirable to produce a sound the cords are drawn across the opening and the air from the lungs forced over them. The effect of this is to cause them to produce sound vibrations. The vibrations of the cords are reinforced and modified by the cavities connected with the larynx.

The Organ of Hearing consists of a contrivance for enabling a sound wave to stimulate the sense-organ cells of hearing and cause them to send impulses to the brain. This organ consists of three parts: The *external* ear, the *middle* ear, and the *internal* ear. The auditory, or hearing cells, are located in the internal ear.

The External Ear consists of the part on the outside of the head, called the pinna, or auricle, and the tube leading into the internal ear, called the auditory canal. This canal is closed, at its inner end, by the membrane of the middle ear, called the membrana tympani.

The pinna, by its peculiar shape, is able to reflect sound waves into the auditory canal which, in its turn, conducts them to the

Membrana Tympani. This membrane consists of three thin layers. The outer layer is a continuation of the membrane lining the auditory canal; the inner, is a part of the membrane of the internal ear; while the middle, is a layer of connective tissue. Being thin and delicately poised, the membrana tympani is easily made to vibrate by the sound waves passing into the auditory canal.

The Middle Ear, or Tympanum, is an irregular cavity in the temporal bone. It is lined with mucous membrane and is connected with the pharynx by a canal, known as the eustachian tube. Extending across it and connecting the membrana tympani with a membrane closing a passage to the internal ear, called the fenestra ovalis, is a chain of three small bones. (Find names for these bones.) The eustachian tube admits air into the middle ear and, in this way, maintains an equality of atmospheric pressure on the two sides of the membrana tympani.

EXPERIMENT. Close the nose and mouth tightly with the hand and attempt to exhale air from the lungs. Account for the pressure in the ears. Repeat the experiment, attempting to inhale instead of exhale.

The purpose of the chain of bones is to transmit vibrations. By means of it the vibrations are carried from the membrana tympani to the

Internal Ear, or Labyrinth. This division of the ear consists of a group of membranous tubes which lie in a corresponding group of bony channels in the temporal bone. There are three parts to the labyrinth: The *semi-circular canals*, the *cochlea*, and the *vestibule*. The different parts are connected, and the cochlea and semi-circular canals may be considered as branches of the vestibule. (Copy drawing from chart, naming the parts.)

Of the different parts of the labyrinth, the cochlea is perhaps the most important, as it contains the auditory cells. It is a spiral tube, coiled like a snail shell, with three internal divisions running its entire length. (Copy the drawing.) One division connects with the vestibule and is called the *scala vestibuli*. Another reaches to the tympanum and is called the *scala tympani*. The other lies between these two and is called the *scala media*, or cochlear canal. This is the true organ of hearing and contains the

Auditory Cells. These are spread out over a thin membrane, called the *basilar* membrane. Fibres from the auditory nerve connect with the cells and transmit their impulses to the brain. Sound vibrations are communicated to them by the liquid which occupies the entire internal ear.

How we Hear. The sound vibrations which originate in some vibrating body are transmitted by the air to the external ear. The pinna and auditory canal direct the vibration against membrana tympani and this is made to vibrate. The vibration of this membrane causes the chain of bones to vibrate and it, in turn, communicates the vibration to the liquid in the labyrinth. This liquid vibrating against the two sides of the scala media, sets the auditory cells into vibration, causing them to discharge nervous impulses. These impulses, *on reaching the brain*, cause the *sensation* of hearing.

PROBLEM: Trace a sound vibration from a bell to the auditory cells and the impulse it causes, from there to the brain.

Many things connected with hearing are not yet understood. The smallness of the true organ of hearing and its position in the temporal bone make its study exceedingly difficult.

The Function of the Semi-circular Canals has not, as yet, been fully demonstrated. On account of the directions which they extend through the temporal bone and the effect which their removal has upon lower animals, they are supposed to assist in keeping the body balanced.

Care of the Ear. The ear being a delicate organ, injury to it often results from careless or rough treatment. The ear wax should not be "picked" out of the auditory canal. The ear has a way of its own for discharging it, besides the practice is attended with considerable danger. Children's ears

should never be pulled or boxed. In removing foreign substances which may have accidently gotten into the ear, use only *gentle* means. In case of serious trouble there should be no delay in consulting a physician.

References:

Review Questions. 1. What is sound? In what kind of bodies does it originate? By what is it carried, or transmitted? What effect may it have upon delicately poised bodies? 2. Define pitch, intensity, and quality of sound. Upon what does pitch depend? Upon what quality? 3. How is a vibrating body able to set the air into vibration? 4. Describe a sound wave. What uses are made of sound waves by most animals? 5. Why is the body supplied with a sound producer and a sound receiver? 6. Describe the method of producing the voice. 7. Make a sectional drawing of the ear, naming the parts. 8. Where are the sense-organ cells of hearing located? How are they stimulated? 9. Give function of the pinna, auditory canal, membrana tympani, eustachian tube, chain of bones, liquid in the internal ear, auditory cells, auditory nerve, and the auditory psychic centers. 10. How do we hear? 11. Why should the ears not be "picked?"

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Light and the Sensation of Sight.

Light is supposed to be a form of wave-like motion, or vibration, thrown off from bodies heated to a very high temperature. Such bodies are said to be luminous. Name examples. Light waves pass from luminous bodies, in straight lines, in all directions. When they strike other bodies they may be *reflected*, *absorbed*, or allowed to pass through. Name a body which reflects light; one which permits it to pass through itself. A single line of light is called a light *ray*. A collection of rays is called a *beam* of light.

When light passes from one medium into another of different density, as for instance from air into water, it is bent out of its course. This bending is called *refraction*. If different light rays are bent so that they meet at a point, they are said to be *focused*, and the point of meeting is called the *focus*. If rays which are reflected from a given point on a body are focused, they form a picture or *image* of that point. A collection of the images of all the reflected points of a body forms an image of the whole body.

Experiments. 1. Heat an iron or platinum wire in a clear gas flame. Observe that as it is heated to a high temperature it gives out light rays, or becomes luminous. 2. With a mirror, a piece of window pane, and a piece of black cloth, illustrate the reflection, transmission, and absorption of light rays. 3. The refraction of light may be illustrated by standing a book, or block of wood, by the side of an empty pan, in the sunlight, so that the end of the shadow falls on the bottom of the pan. Mark the place where the shadow terminates and fill the pan with water. Account for the shadow's changing in length. 4. Place a coin in the center of an empty pan and have the members of the class stand where the coin is barely out

of sight over the edge of the pan. Fill the pan with water and account for the coin's coming into view. 5. Hold a piece of card-board, about 8 inches square and having a smooth, round hole in it an eighth of an inch in diameter, in front of a lighted candle in a darkened room. Back of the opening place a muslin, or paper, screen. An image of the candle will be formed on the screen. Account for the fact that it is inverted. Make a drawing to represent its formation. 6. Hold a convex spectacle lens between the card-board and screen so that the rays of light pass through it. The image should become smaller and more distinct.

A complete knowledge of light can only be obtained by a study of Physics. A slight knowledge of it is necessary here, because light rays stimulate the sense-organ cells of sight and thereby enable us to see objects. In order *to see an object* four things must happen: 1. Light rays must pass from the object to the eye. 2. These rays must stimulate the sense-organ cells to discharge their impulses. 3. These impulses must be transmitted to nerve centers in the brain. 4. These centers, in response to the impulses, must become active. This activity is the sensation of sight.

The Organ of Sight consists of the eyeball, or globe of the eye, together with the tissues for its protection and control.

The Globe of the Eye is a contrivance for focusing the rays of light from an object, upon the sense-organ cells of sight. Its parts are as follows:

The *cornea*, a clear, transparent membrane, is in the center of the front of the eye. It fits into the sclerotic coat which surrounds it on all sides, as the crystal of a watch into its case. It admits light into the globe. The *sclerotic coat* is white, dense, and firm. It surrounds the remaining portion of the eyeball, except where the optic nerve enters. At this place it continues back as the sheath of the nerve. The portion of it seen in front, is called the "white of the eye."

The sclerotic coat is lined by a dark colored coat, the *choroid*, which is crowded with the blood vessels that furnish most of the nourishment to the eye. On account of its color it is able to absorb surplus rays of light. The choroid coat is continued forward into the circular curtain back of the cornea called the *iris*. The iris is the colored portion of the eye. In the center of the iris is a circular opening called the *pupil*. This opening is to admit light into the inner portion of the eyeball and its size is regulated by the iris. The iris contains two sets of involuntary muscles—one set, of circular muscles, surrounds the pupil, and the other, of radiating muscles, are attached between the inner and outer margins of the iris. What effect will a contraction of the circular muscles have on the size of the pupil? What, the contraction of the radiating muscles? By increasing and diminishing the size of the pupil, the iris is able to regulate the amount of light which enters the inner eye.

Lying next to the choroid coat, in the back portion of the eyeball and covering about two-thirds of its inner surface, is the *retina*. Though only about one-fiftieth of an inch in thickness, it is very complex in structure and contains the *sense-organ cells of sight*. These cells, on account of their peculiar shapes, are called the *rods* and *cones*. Fibres from the optic nerve

connect with these cells and conduct their impulses to the brain. That portion of the retina immediately back of the pupil, called the *yellow* spot, is the place where it is most sensitive. At the place where the optic nerve enters the eye, the rods and cones are absent. This is called the *blind* spot.

EXPERIMENT. Close the left eye and with the right gaze steadily at the spot on the left side of the page. Starting with the book a foot or more from the face, move it slowly

toward the eye. One place will be found where the spot on the right entirely disappears. On bringing it nearer, however, it is again seen. As the book moves forward or backward, the position of the image of this spot on the retina changes. Where is it when the spot cannot be seen?

The *crystalline lens* is situated immediately back of the iris. It is a transparent solid body, convex on both sides, being about one-third of an inch in diameter and one-fourth of an inch thick. It is quite elastic. It is surrounded and held in position by a membranous capsule, the edges of which, connect with an extension of the supporting connective tissue of the retina.

Surrounding the lens, and lying at the junction of the iris and choroid coat, is a circular band of involuntary muscle, called the *ciliary muscle*. Its contraction has the effect of diminishing the diameter and increasing the thickness of the lens.

The eye contains two liquids. A watery liquid which lies between the lens and the cornea, is called the *aqueous humor*. It serves to hold the cornea in shape. Lying between the lens and retina is a clear jelly-like liquid, called the *vitreous humor*. This serves to hold the walls of the eyeball in shape. (Copy from the chart the drawing of the globe of the eye and name its parts. Practice on this drawing until it can be made from memory.)

EXPERIMENT. In the center of one end of a chalk box, having a tight fitting lid, cut a round hole half an inch in diameter. Over this hole fasten a small piece of tin which has in its center a smooth, round hole three-sixteenths of an inch in diameter. Back of the hole fasten by a suitable support a convex lens, such as may be obtained from an old pair of spectacles. At the upper left hand corner of the same end of the box, cut another opening, making it one-fourth of an inch in diameter. Fit a stiff piece of white paper in the back end of the box and arrange it so that its position may be shifted.

If the lid be placed on the box and the opening in the center turned toward a window, an inverted image will be seen on the paper screen by looking in the hole at the corner of the box. Care must be taken that the head does not obstruct the rays of light which pass from the window to the hole. The distinctness of the image will be increased by a coat of black paint on the inside of the box. Compare the box to the eyeball, part for part.

Focusing Power of the Eye. The instruments used in Physics for focusing light rays are called lenses. The eye is provided with two of these. The cornea with the liquid behind it, forms one of them and the crystalline lens is the other. Light rays from the surfaces of bodies are, by means of these brought to a focus upon the retina.

In focusing objects, at different distances, it is necessary for the crystalline lens *to change its shape.* In focusing the rays from *near* objects, it becomes *thicker* and more convex than when focusing the rays from *distant* objects. These changes are brought about by the capsule and ciliary muscle working in opposition to the elasticity of the lens. When the lens is to be made more convex, the ciliary muscle contracts and presses the lens out of its natural shape: when less convex, the ciliary muscle relaxes and the elastic force of the lens makes it thinner. The changing of the shape of the lens to suit the distance of the object is called *accommodation.*

EXPERIMENT. Hold a pencil between the eyes and window, looking at the window. Why does the pencil appear blurred and indistinct? Keeping the pencil in the same position look at it instead of the window. Account for the appearance of the window. Look from one to the other several times in succession. Is it easier to change the gaze from the distant to the near object, or vice versa? Why?

How We See. Rays of light from objects enter the eye and are focused by the cornea and crystalline lens upon the retina. Here they stimulate the rods and cones causing them to send the impulses to the brain which cause the sensation of sight. Review the parts of the eye and determine how each part helps in the matter of seeing?

Defects in Focusing Power. An eye in a natural, or normal, condition is able, when at rest, to focus objects which are 20 feet or more away and is able to *accommodate* itself to objects as near as five inches. An eye is said to be *myopic* or *shortsighted* when it is unable to focus light rays from *distant* objects. In such an eye, the ball is too long and the image falls in front of the retina. A *longsighted* or *hypermetropic* eye is one which can focus the rays from distant objects but not those from near objects. In such an eye the ball is so short that the image of the object, if formed, would fall behind the retina. These defects in focusing are remedied by wearing glasses whose lenses are shaped so as to correct the defect in the eye. Shortsightedness is corrected by a *concave* lens and longsightedness by a *convex* lens. Why?

In *astigmatism* all parts of the eye fail to focus at the same distance. As a result one part of an object is seen distinctly while another part is dim. This defect is due to some fault in the crystalline lens. It is remedied by lenses ground to correct the particular defects which happen to be present in a given eye.

The Movements of the Eyeball are brought about by the action of six small muscles attached to its outside. Four of these, the *recti* muscles, are attached between the upper, lower, inner, and outer sides of the ball, and the back portion of the socket. These are able to turn the eye upward, downward, inward, and outward. The other two, the *oblique* muscles, are attached between the upper and lower portions of the ball and the sides of the socket. These rotate the eye. (Copy and understand the drawing.)

How the Eyeball is Protected. 1. By the bony cavity in which it is placed. 2. By cushions of fat which line the cavity. 3. By the lids. How? 4. By a thin sensitive membrane, the *conjunctiva*, which covers the front of the ball and the under surface of the lids. This membrane prevents foreign bodies from getting behind the ball. 5. By the tears. How? (Study the plan by which the tears are supplied to and removed from the eyes. Copy drawing.) 6. By the eyebrows and eyelashes. How?

Care of the Eyes. On account of their delicacy the eyes are easily injured by careless use. If the following precautions are observed many of the common ailments of the eyes may be prevented: 1. Never read where the light is very intense or very dim. 2. When the eyes hurt quit using them. 3. Never hold a book so that the smooth page reflects light into the eyes. The best way is to sit or stand so that light passes from over the shoulder to the book. 4. Never study by a lamp which is not shaded. 5. When the eyes are weak, wash them frequently in water containing enough salt to slightly smart them. When something serious affects the eyes, consult a physician.

References:

Review Questions. 1. What is the supposed nature of light? In what kind of bodies does it originate? 2. When is light reflected? When absorbed? When refracted? When transmitted? 3. How is an image formed? 4. What different things must happen in order that we may see an object? 5. Make a sectional drawing of the eyeball and name its parts. 6. Give the function of the cornea, pupil, iris, retina, choroid coat, sclerotic coat, crystalline lens, ciliary muscle, optic nerve, aqueous humor, virtreous humor, and conjunctiva. 7. Trace a ray of light from a visible object, through the different media, to the retina and the impulse it causes from there to the brain. 8. What portions of the eyeball are transparent? Why should they be? 9. What is accommodation? How is it accomplished? 10. What is the focusing power of a natural eye? When is an eye myopic? When hypermetropic? 11. What is astigmatism? How is it remedied? 12. Show how the different movements of the eyes are brought about. In what different ways is the eyeball protected? 14. Describe the conjunctiva and give its function. 15. Give directions for the proper care of the eyes.

Hygiene of Nervous System.

Like other portions of the body the nervous system, particularly the brain, may be injured by overwork, or by careless treatment, and improved by proper care and use. Mental work is conducive to the health of the nervous system. Even severe mental exertion may be undergone without bad effects, provided proper hygienic conditions are observed.

Plenty of Sleep is one of the first requirements of the nervous system. This is the time during which the exhausted brain tissues are being replenished. To shorten the natural period of sleep is to weaken the brain and lessen its working force. No one should attempt to get along with less than eight hours of sleep each day and most people require more.

Physical Exercise is another requirement of healthy nervous action. (See topic on physical exercise, p. 78.) Mental work causes an excess of blood to be sent to the brain and a diminished amount to other parts of the body. Sufficient physical exercise should, at least, be taken to redistribute the blood and equalize the circulation. Light exercise, therefore, should follow hard study. The student on retiring at night is greatly assisted in getting to sleep, and put in better condition for the next day's work, by 15 or 20 minutes of light gymnastics.

Fretting and Worrying are unhealthful forms of nervous activity which should be carefully avoided. Certainly the vast quantity of nervous energy which may be expended in these ways cannot be used in doing mental work. A fretting person may be likened to the leaking boiler of a steam engine. The escaping steam not only lessens the working power of the engine but is disagreeable and distracting as well. "It is worry not work that causes the mental wreck."

Mental States have much to do with the healthfulness of the nervous system. Angry and resentful feelings and manifestations of envy and jealousy are known to work positive injury to the nervous system as well as the disposition, while *brooding* over real or imaginary wrongs has caused many cases of insanity. On the other hand, cheerfulness, contentment, patience, and manifestations of good will and good fellowship are necessary conditions for healthful nervous action.

What We Eat and Drink also has an important effect upon the nervous system. Like other portions of the body, it fares best when there is a liberal supply of wholesome, well-cooked food. There is a class substances, deserving special consideration, which have an important effect upon the nervous system without themselves undergoing any change in the body. These substances are of two general kinds, known as

Stimulants and Narcotics.

Stimulants act upon the nervous system to *increase* its activity while the general effect of narcotics is to *lessen* its activity. Although the use of these drugs in disease may be beneficial and often invaluable, the frequent use of them in health is decidedly injurious. Among some of the more common ones may be named *alcohol*, *morphia*, the *nicotine* of tobacco, the *caffeine* of coffee, and the *theine* of tea.

Alcohol is the intoxicating principle in the usual saloon drinks such as whisky, beer, ale, wine, etc. It is formed by the fermentation of fruits and grains. When pure it is a colorless liquid, lighter than water, with an agreeable odor and a hot, pungent taste. It is inflammable, and burns with a clear, hot flame. It is able to dissolve many substances in water, such as oils, gums, and resins. It has a strong affinity for water and is able to absorb it from organic substances. Its first effect upon the nervous system is that of a stimulant, though in large doses it acts as a narcotic.

Experiments. 1. Place a tablespoonful of alcohol in a saucer and ignite it with a burning match. Observe that the flame contains no soot and gives little light but great heat. 2. Pour some alcohol over the white of a raw egg and observe the effect. The coagulation of the albumen is due to the absorption of water from it by the alcohol. 3. Place a drop of blood on a glass slide and place over it a cover glass. Examine under a compound microscope. Then add a tiny drop of alcohol to the blood on the slide and examine a second time. The shruken condition of the corpuscles is caused by the alcohol coagulating the albumen in them.

Alcohol has some very important uses. It is used as a combustible for obtaining a hot, smokeless flame. It is used in dissolving gums, oils, and resins for medical purposes and for use in the arts. It is used by scientists in preventing the decay of animal and vegetable substances and, by some physicians, in the treatment of diseases where a stimulant is needed.

The Evil Effects of Alcohol lie in its use as a beverage. It has been proven to be a poison, whether used in large or small quantities, and is in no sense to be regarded as a food. Introduced into the body, it weakens the nervous system by making it *too* active; it hardens the tissues by absorbing water from them; it interferes with digestion and the natural circulation of the blood; it so disturbs the action of the brain as to induce *temporary insanity*, or drunkenness, which, if frequently repeated, leads to permanent insanity; it rapidly weakens the stomach, liver, and kidneys, rendering them unfit for their important work. But, worst of all, it creates an appetite for itself that causes the victim to take it in larger and larger doses until death or insanity is the result. As a beverage, alcohol, in all its forms, should be carefully avoided, and its use even as a medicine is gravely questioned.

Alcoholic drinks are often used for the purpose of keeping the body warm. By stimulating the circulation and increasing the flow of blood through the skin it will make one *feel* warm. But for the reason that it

Charley

undergoes no chemical change in the body it furnishes no heat. In the end bodily heat is diminished by taking alcohol and, as soon as its stimulating effects are over, one will suffer intensely if exposed to severe cold.

Morphia is perhaps the most powerful and dangerous of the narcotics. It is an extract from opium and is a valuable medicine. Its use, however, is attended with great danger, as the opium habit is easily contracted and is even worse in its effects than the alcohol habit.

Nicotine is an oily, colorless liquid obtained from tobacco. It is eminently a poison. Taken in very small quantities it is a mild stimulant and if the doses are repeated a habit is formed which is very hard to break. Tobacco is used for the peculiar stimulating effects of this drug. The tobacco habit, while not so serious in its results as the as the alcohol and morphine habits, is of no benefit, is a great and useless expense, and, in many instances, causes a derangement of the healthy actions of the body. Its use by the young is especially injurious, as it decidedly interferes with the proper development of both body and mind. To the bad effects of the nicotine may also be added those of questionable substances used either for their agreeable flavor or as adulterations. Perhaps the worst thing yet produced in the tobacco line is the cigarette. Its use has been the direct cause of many deaths within the last few years.

The Caffeine of coffee and **Theine** of tea are mild stimulants, and it is for the effects of these drugs that tea and coffee are so extensively used. Tea and coffee are similar in their action, though they affect persons differently. Where the system needs a stimulant they are preferable to alcohol. Their habitual use, however, interferes with the healthy action of the body and for that reason should be avoided. Brain workers especially experience bad effects from their use. The continued practice of some students of drinking coffee and tea in order to study late at night can only end in the loss of health.

References:

Questions. 1. Of what value is sleep to the nervous system? 2. What is the special value of physical exercise to the brain worker? 3. How do fretting and worrying lessen one's power to work? 4. What mental states are conducive to the healthfulness of the nervous system? What ones interfere with its healthy action? 5. How do stimulants differ from narcotics? How do both differ from foods? 6. Give the properties and uses of alcohol. 7. What are a few of the bad effects which it has upon the body? 8. How is alcohol able to make one *feel* warm? 9. What bad effects has nicotine upon the body? 10. Is the general effect of tea and coffee beneficial or harmful? 11. Why do brain workers experience worse effects from the use of stimulants and narcotics than others?